HEMISTRY

$1.00

Show to Know

➤ SINCE *early men in the caves of France and Spain drew pictures to depict their deeds and the animals they had seen and killed, more modern men have been exhibiting their skills and accomplishments in a variety of manners.*

Markets, fairs, exhibitions, displays, shows—almost every field of human interest has them almost everywhere, in every language, and in every climate.

The science fair or exhibit as an adjunct to youthful participation in science as a study or a hobby has most widely developed in America.

Some of these are very simple, such as the showing of the projects of the members to a school's science club. Or in a large city there may be over a thousand exhibits assembled under one roof for the public to see and appreciate.

The purpose of this collection of EXHIBIT TECHNIQUES *is to bring together material that will be of aid to the prospective science exhibitor who may never have done a project and displayed it to public view. It is intended to aid teachers and club sponsors who are asked questions by their students.*

Those who will do their projects and construct their exhibits in the future will undoubtedly feel that they have done better than some of the efforts described. That is as it should be, for the future should be better than the past. There is one sure thing in science and that is that the future will be different from the past and that there will always be change.

Exhibits and fairs, in the field of science, are important instruments in communication of scientific information. In science, you must know to show and you should show to know.

CHEMISTRY

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Including The Science Leaflet

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➤ STUDENTS *enjoy showing their science hobbies to classmates and visitors from other schools. This photograph of a recent local Science Fair was taken by one of the exhibitors.*

An Exhibit Tells a Story

➤ AN EXHIBIT of scientific work tells a story. When you build and show such an exhibit you are striving to tell your audience how some part of the world around you has come to have special meaning for you.

The most successful approach in telling such a story comes usually from an exhibitor whose topic has grown out of a hobby. The most despairing approach is: "I've got to have an exhibit. What would make a good one? What do the judges want me to do?"

People in many kinds of activities have occasion to make displays showing some process involving materials. Chemists, especially, work with natural substances, with the processes by which such substances are manipulated, and with manufactured products which, they hope, will be useful to their fellow-men. For this reason the editors of CHEMISTRY include in

this volume data on exhibits outside the narrow field of chemical experiments. Chemists have a hand in every kind of material, for every sort of use.

Science hobbies often begin with collections of natural objects, such as stones or sea-shells. Small children are usually avid collectors of such material, and many scientists date their interest in their specialties back to their childhood hobbies.

Living plants and small animals interest other collectors. Some find pleasure in assembling preserved samples of many different objects and arranging them according to some classification scheme. Others like to maintain living collections in gardens, in aquariums, as pets, or even in private zoos.

Mechanically-inclined people often try their hands at constructing scientific instruments. Many amateur astronomers grind lenses and construct telescopes. Cameras and spectroscopes are frequently added.

Mass spectrographs, Geiger counters and scintillation counters are among the newer instruments which amateurs can make and use. Electroscopes and cloud chambers are standard pieces of apparatus for making charged-particle ionization visible. The new interest in atomic phenomena prompts many amateurs to build such instruments to explore their surroundings from a new angle.

Process stories, showing raw materials and steps in manufacture, are especially prominent in chemical exhibits. Occasionally a pilot-plant operation can be carried out on a miniature scale, so that visitors can watch actual transformations going on before their eyes. This has all the charm of a "magic" show. It is, however, difficult to keep in operation properly, and potentially dangerous to the public if breakage or leaks occur.

A frequent compromise simulates parts of the apparatus, using drawings and photographs. Samples of raw materials and finished products are shown, and sometimes intermediate products which contrast with the other materials.

Industries centered in the neighborhood are often taken as the theme of local exhibits. These are of particular interest to visitors who can identify the parts they play in the process pattern displayed.

Similar layouts, showing the relationship of local topography and geological outcrops to the kinds of manufacturing, mining, farming or other activities characteristic of the region, are of general interest.

Subjects of a more technical nature require different types of presentation according to the audiences to which they are to be shown. A process can be explained to a group of technicians, familiar with similar processes, with minimum use of showmanship. The demonstrator must, however, be able to answer detailed questions in a manner satisfactory to his audience.

To explain the same process to casual visitors whose special interests lie in different fields, a great deal of material related to every-day experience must be brought into the exhibit to catch their interest. Technically trained people are often impatient with this approach, which is unnecessary for them.

When exhibits are to be placed in competition, the problem of pleasing the technically-trained judges is super-

posed upon the basic problem of pleasing the general audience.

Since the choice of subject is usually left to the exhibitor, the question arises as to whether the chosen subject comes within the scope of the show. This leads eventually to the question: "What is science?" which can be as broad as the universe.

Material presented here is designed, not to tell the reader what to show, but to help him with some of the technical details of how to show his exhibit.

From chemists we have borrowed methods of making interesting chemicals and isolating unusual substances. From naturalists we have taken ideas for making collections and caring for growing things. From physicists we have collected directions for constructing and using instruments for scientific observation and measurement.

Museum experts have contributed ideas on displaying the resulting treasures. People with many kinds of experience in packing and shipping offer valuable hints on how to take your exhibit to the science fair and bring it home safely.

The object of this material is to give the inexperienced person, of whatever age, some practical pointers on designing, constructing and caring for the materials which tell the story of his interest in science.

How Fairs Are Organized To Show Student Projects

Come to the Fair!

➤ "Come to the fair" is the invitation from Science club members when they exhibit their projects to their fellow students, teachers, parents, and the public.

Science fairs are now just as fundamentally a part of American life as are the country fairs that did so much to build our agriculture and industry.

The simplest of fairs consists of an exhibition of science projects held in the school itself. There are shown all the experiments, collections, and displays that have been worked out by students either in class time or as extra-curricular science club activities. In this form only the other boys and girls and the teacher see the exhibits; but enthusiasm soon spreads to make them a feature of a meeting or a showing to which parents and the public of the community are invited

The exhibits, considered most likely to compete favorably with those from other schools and clubs, are sent to city-wide or area science fairs.

In holding a science fair in a locality, the schools, industries, colleges, and newspaper usually cooperate. A teacher's committee takes the initiative and a newspaper, as part of its educational service to the community, often will sponsor it, assisting on the publicity, promotion, arrangements

and financing. Science Clubs of America, administered by Science Service, Washington, D. C., will make available the "know-how" of conducting a fair. This has been acquired from aiding and observing the hundreds of science fairs that have been held in recent years in various parts of the country.

Honors and Awards

Exhibitors in the fair are rewarded by the stimulation of having their work shown and by receiving certificates indicating the impression their work made on the judges. These correspond to the red, blue, and white ribbons of agricultural fairs. Other awards, ranging from emblems to cash prizes and scholarships, are sometimes given.

A typical science fair will have several hundred exhibits, viewed by thousands of people who visit an exhibition hall which may be a school or college gymnasium, an armory, a museum, or other such area. Some science fairs, even in large cities, accept the maximum number of exhibits the hall will allow. In other cases, the city or area fair receives only an allotted number of exhibits from each school which holds its own eliminations first.

The exhibits are judged by committees of scientists, engineers, and other experts of the community, using rules adapted from judging standards now nationally approved. These are available to those requesting them.

Local science fairs usually are held not later than April so as to allow students and club members to work on their projects during most of the school year and also give enough time for entering the national event. Often projects are started as soon as school opens in the fall, and some students get "a head start" by working on exhibits during the summer vacation.

The National Science Fair

At local fairs the best exhibits are selected for entry into the annual National Science Fair, held in a different city each year, under the auspices of Science Clubs of America and cooperating newspapers. Usually an even number of boy and girl Finalists are selected and are sent to the National Science Fair as guests of the local cooperating newspaper.

The exhibitors whose projects are judged best in local competitions are eligible to enter the National Science Fair when sponsored to this event by a local newspaper. The newspaper sends the finalists and exhibits to the city where the National Science Fair is held.

Each finalist receives a rainbow-ribboned solid gold and silver medal engraved with his or her name and that of the host newspaper. A facsimile medal and certificate is sent to the principal of the school of each finalist to become a trophy in the school's collection.

On the basis of critical judging, 12 finalists receive "Wish Awards" — selected scientific equipment and materials which each winner feels will help him in the furtherance of his study and experimentation.

All finalists participate in a three-day program of scientific sightseeing and meetings with leading scientists as well as the public. At the same time they become acquainted with other finalists having similar inter-

ests, compare work of others and thus carry back to their local situations an enthusiasm and stimulation that will be reflected by others in future years. A record of the subsequent achievements of all finalists is being maintained to evaluate further the program as a means toward encouraging future scientists, engineers, and technicians.

Educationally Valuable

The whole science fair program is educationally sound. It allows the student to select freely the project upon which he plans to work. Automatically he leads himse'f through a study of the bed-rock principles of his chosen topic, thus acquires a basic, fundamental understanding of the facts and techniques involved. After he shows his exhibit he can personally evaluate what he has done and compare it with the efforts of others of his own age who have similar interests. As a result he sets new horizons for himself and tries to better previous records. It has been well established that a satisfactory evaluation of skills can be made only by comparing exhibits against each other both at local and national levels. Every area in which fairs have been held several years in succession reports that current exhibits become better year by year.

Soilless Growth of Plants Makes Attractive Exhibits

Hydroponics a Typical Project

➤ MAKE the container for your soilless garden 6 ft. long, 3 ft. wide and 10 inches deep. Build it of lumber, or form it of concrete. Then coat the inside with non-toxic asphalt or a similar harm'ess waterproofing material.

Well-washed sand or ca!careous gravel is then put in, to serve as an anchor for the plant roots and at the same time provide aeration.

One end of the bottom of the container must be an inch or two lower than the other, to allow excess nutrient solution to drain off. Provide a sump tank to catch this overflow. It should be similar in construction to the garden container itself.

The nutrient fluid, which is run in at the higher end of the garden bed, is used to flood the garden twice a day, at 12-hour intervals. A typical formula for such a solution follows:

Potassium nitrate — 6 lbs.
Ammonium sulfate — 1 lb.
Magnesium sulfate — 4½ lbs.
Mono calcium phosphate — 2½ lbs.
Calcium sulfate — 11 lbs.
Water — 1000 gal.

Trace elements, such as iron, fluorine and boron, should be added in small amounts, in the form of salts. The above quantities make about ten times the capacity of a garden bed of the size given. The whole amount does not have to be mixed at one time, but materials should be combined in the same proportions. Use technical grade chemicals rather than C.P., to take advantage of the trace e'ements they contain.

Ideas That Will Save Time and Energy for Science Exhibitors

Hints for Science Fair Exhibits

Out of the years of experience of science fairs in which many thousands have participated, much has been learned that will be useful to those who are working on science exhibits. Joseph H. Kraus, coordinator of the National Science Fair, has compiled these suggestions which any prospective exhibitor will find useful.

➤ Before starting actual work on any exhibit which you hope to enter in any science fair, consult the rules of the local competition to determine the requirements and the space available to you.

Nearly all local contests, and the National Science Fair as well, recommend that the exhibit be contained within an area of a cube measuring 3 feet on each side. Some local rules make this a requirement. Some limit the space to a smaller area. Others have no space rules. But even if you could spread your exhibit over a very large space, it will make a more interesting exhibit if you attempt to concentrate the parts of the exhibit so that they will come together more compactly.

Any exhibit winning top honors locally and entered in the National Science Fair will be accepted regardless of size. At the national level it is realized that some exhibits cannot be shown properly if space is limited. Collections of butterflies, insects, plants, birds, bird nests, chemicals, bones, minerals and other things may be quite incomplete if they must be divided up to fit within a limited area. Some things may not operate if limited in space. It would be unrealistic to limit the construction of a telescope, Van de Graaff generator, light beam transmitter, short wave radio, wave apparatus of certain pendulums to an arbitrary space. For such as these it is recommended that local fair committees accept oversize exhibits when more space is needed for proper display.

Most exhibitors who never saw a science fair tend to spread their exhibits "all over the place." Many make large, crude illustrations, letter the exhibits as though the signs are to be read at a distance of 100 feet or more, spread notebook records over the entire table top, etc.

Judges will usually give no favorable weight to the size of the exhibit. It is what is shown in the space that is important.

Plan Exhibit First

Assume that you will have a 3-foot cube of space into which to place your exhibit. Cut four pieces of wrapping or newspapers 3 feet square each. Two of these are most important since they will pattern the base and back of the exhibit. The sides are less prominent and the material to be placed there should be secondary in importance unless the side panels tell

a running story. It is better to tie in the side panels to the base and center panels.

If you are good at visualizing, mark in bold pencil or crayon the place on the base which will be occupied by the most important feature of your exhibit. Do the same on the back panel. Then locate around this where you will put other details. Box areas where lettering will be placed.

If this sort of pictorial imagination is not easy for you and you know what major articles you hope to include, you can use a spotlight or flashlight to cast shadows. You can now mark where they fall to give you an idea how the parts of your exhibit should be placed.

The important feature of your exhibit need not be located at the center of your exhibit space. A good example to follow is the setup of any natural habitat group in any museum. Often the attractive feature is in the right or left foreground. The main object is to establish a pleasing picture that is not too much cut up. If there is not a museum near you, you can study window displays while walking back and forth to school. Observe the helter-skelter type of displays in grocery, drug, hardware and variety stores. These are not designed to tell a story but rather to attract attention by a mass array. Then compare with an exhibit likely to be found in large department store windows, particularly those involving a display of ladies' dresses or winter coats. Notice also how side panels are used only for secondary interests. This is good practice, but is not always best for every exhibit.

Decide on what descriptive material you will need. Decide just where you will place the title of your exhibit and where you will locate the legends. Indicate the space which you will need for lettering. Remember that the title should be brief and preferably easily understood. You are trying to interest the public in what you are doing, not demonstrating how much you know about technical phrases.

With materials accurately located and with legends so arranged that they will not be hidden by a piece of equipment you are now ready to go to work.

Knockdown Panels

For ease in transportation, perhaps the simplest construction is in the form of panels which can be joined together quickly. Wallboard, plywood, pressed wood or similar materials may be cut to size for the back and two sides. If many small articles are to be displayed it may be well to provide a panel which will be the base. If you wish to enclose the exhibit area more completely, you can arrange for a top and even a front.

How to connect the panels together so that they will stay in place is largely a matter for your ingenuity. A couple of screweyes, nails or cleats arranged adjacent to each other will permit the panels to be lashed together by strings or shoelaces. Better is the use of loose pin hinges. Hinges are screwed to the outsides so that they straddle the edges. Two hinges for each joint will suffice. Then the hinge pins can be knocked out and the panels may be separated one from the other. For a good fit around the

base it is well to add narrow wooden cleats so that the hinges will lie flush. Rubber tacks or chair domes may be used instead. Make sure that you provide a support at the middle so that the base does not sag with the applied weight.

You may wish to box your exhibit completely. This will be advisable if you hope to arrange a diorama, or display a radio transmitter, receiver or electronic circuit or if you display valuable small parts.

Thousands of people will view your exhibit. It is impossible to protect at all times every area of a fair. You should take reasonable precautions against loss or damage. It is advisable to box in any exhibit from which parts are likely to stray. The public should be protected from any portion of your exhibit that might be a hazard. The knockdown panel form of exhibit can be protected over its face by a sheet of clear plastic. Wire screening can be used although this covering gives a messy appearance to an otherwise good exhibit.

There are many ways to attach parts to the panels. If small enough they may be attached with tape or cement. Heavier pieces can be secured by drilling small holes through the panels and wiring the parts in place. Rigid or demountable shelves will be found useful to hold some of the material which you can drop in position while setting up. Picture hooks driven into the panels will make it easy to hang on prepared groups. Decorative plate holders may be used to hang petri dishes and similar objects. Test tube racks may be suspended instead of being arranged on the base. If the construction requires electric wiring it would be well to mount permanently a plug-in socket into which a plug can be pushed for a quick connection to a supply source. But do not wire your exhibit for current unless you actually need it.

You should be able to arrange your material so that it can be set up quickly and knocked down just as fast. If you preplan your exhibit, this will be easy. For example, use a multicord conductor for interconnecting electrical parts instead of trying to make individual connections. Do your soldering in your laboratory instead of at the site of the fair.

Dangerous Materials Prohibited

Strong acids, alkalis, flames, explosives and materials liable to spontaneous combustion cannot be displayed at most science fairs. They cannot be entered in the National Science Fair because they cannot be shipped or carried on airlines. This does not mean that any exhibit based on the use of a strong acid or alkali would be barred. A safe substance should be substituted for the dangerous chemicals in the display and labeled as a substitute.

Liquefied gases, poison gases, poisons, etc., cannot be displayed. Bacterial cultures should be sealed to protect against tampering. Your story can often be told as well with a bottle of water as with a container of gasoline, since their contents look alike and water can safely simulate gasoline in a display.

You do not need to demonstrate how you produced some of the things shown in your exhibit. You can put an unlighted Bunsen burner under your

glass set-up and show the end product even when dangerous chemicals or techniques were used in the process. No matter how familiar and expert you may be with the materials you handle in your laboratory, the public must be protected against any hazard. You will not be in attendance with your exhibit all the time it is displayed.

Livestock and Live Plants

Live animals cannot be entered in the National Science Fair because of the difficulty of proper attention and feeding during transportation and at the fair. Microorganisms, fruit flies, fish, insects, and similar living material may be shown.

Federal and state regulations may make it difficult to ship growing plants to the exhibit area unless they are certified as disease and insect free. Some plants, fruits, vegetables and plant products cannot be shipped from some areas to others at all. If you are contemplating this type of exhibit and hope to enter the National Fair it would be well to check with your State Board of Agriculture. There is no objection to photographs, of course.

Lettering and Labels

Huge letters poorly made, ponderous charts or diagrams, notebook records spread across the table top do not contribute to a good exhibit. Judges and spectators come close up to exhibits. It is not necessary that the letters or charts be so large that they can be read from a distance of 100 feet or more.

The visitors in a few minutes will be expected to grasp the meaning of what it may have taken you months or years to prepare. So make your major legends small, neat, readable at a distance of 6 to 8 feet. Those who will want to study your notes will gladly leaf through your notebook which preferably should be secured to the right hand front edge of your exhibit space.

To make neat lettering, various sorts of lettering guides and aids may be secured from your local draughting supplies store. Small and large plastic letters can sometimes be obtained from local restaurants where they are used to compose displayed menus. Ask for letters that have been discarded. When the lugs on such letters break they are of little further use and generally are discarded. Cut off all the lugs and trace around the letters. Or you can use stencils and fill in the open space.

Thin strips of colored cellophane tape, such as is used for binding Christmas packages, may be used for producing angular letters by attaching the strips to a background.

Letters from newspapers or from magazines can be cut out and used. However, this generally makes a very crude job. It is best to use the letters merely for shape, style and size, tracing them on another sheet. An easy trick in this connection, is to moisten a sheet of good bond paper with lighter fluid, which makes the paper transparent, then trace the letters upon the bond paper with a pencil. Because of the fire hazard, keep flames away and work in a well ventilated room. When the lighter fluid evaporates, the paper will resume its opacity. If the fluid evaporates before you finish the job, you can swab on more of it.

Prepare the text of your legends carefully. Write what you want to say, then set it aside for a day or so, then go over it again. You may want to eliminate useless words or change the text completely. Locate this lettering where it can be read easily. If it calls attention to some part of the exhibit, try running a ribbon from the lettering to that part of the exihiibt. If you use several ribbons get some balance in the way they are placed. This may mean shifting slightly the sign or the material. Do not cross ribbons, to avoid confusion in direction of attention.

Safe Construction

Normal wear on moving parts must be expected in exhibits. Hence they should be made sturdy enough to take the punishment of operation and display. If you plan to use push rods, levers, wheels, and pulleys which you expect the spectators to operate, make sure to that you provide stops to limit the motion in either direction, so that even if the controls are forced they will not give way. Try to get as many things as possible working automatically. In any sequential operation do not depend on the fact that your directions read to do this first, then that. Have this sort of operation entirely automatic. The average spectator will push a button first, then read the instructions. If such faulty operation will jam the mechanisms, you should substitute some other controls.

Wire down any loose materials so that they cannot be removed. Use strong iron wire. Lock down any magnifier. Better yet, mount it under a box provided with a peep hole and fasten the box securely. Chain down any miscroscope, camera, optical instrument, microphone, earphones, and preferably enclose vacuum tube circuits in a cabinet. Lock the adjustments on a microscope so they cannot be manipulated except for the fine adjustment. This may save you a slide or lens. If the scope is a good one it can be covered with a box containing only a peep hole. Make sure that the eyepiece of the instrument cannot be removed.

Every fair attracts avid souvenir hunters who will pocket loose apparatus as mementos. So guard against this. In all science fairs, equipment and exhibit is entered at the risk of the exhibitor. Neither the committee nor any sponsor is responsible for loss or damage.

Electrical Safety Rules

To prevent shock or fire certain electrical safety rules apply at all fairs. Generally, failure to comply with these rules automatically disbars an exhibit.

For 110-volt operation of lights, motors, transformers and all other equipment, insulated cord of the proper load carrying capacity must be used. At least 6 feet of wire should be provided with the free end fitted with a parallel prong plug. Where surges or overloads are anticipated it will be well to fuse the exhibit.

Nails, tacks or uninsulated staples should not be used to fasten wire to the equipment. Use plug or outlet securely attached to the exhibit or any standard connector.

Use toggle, pull chain or push switches or other standard controls for all 110-volt circuits. Open knife

switches or bell ringing push buttons are not acceptable.

For low voltage circuits where the current draw is light, bell-ringing push buttons may be used in the secondary low-voltage side of a transformer circuit or for dry cell or storage battery operated device.

Plan to locate your storage battery on the floor under the table and behind the exhibit. Preferably introduce an auto cartridge fuse as close to the battery terminals as possible. This will protect your battery should a short circuit occur.

Bell wire may be used for low-voltage small-current-carrying loads only. It must not be used on 110-volt circuits.

All electrical joints in 110-volt circuits should be soldered or fixed under approved connectors. Bare wires should be taped in load-carrying circuits.

High-voltage equipment should be shielded so that accidental contact with charged condensers or high-voltage electrodes is impossible. A grounded metal box or wire cage will be satisfactory. Exceptions can be made in those constructions in which the high-voltage discharge is relatively harmless, as for example, Tesla and Oudin coils, static machines and van de Graff generators.

Large electron tubes should be placed behind a glass shield.

Do not use line cord resistors for radio sets.

Protect with asbestos board of adequate thickness on sides and base any exhibit which will produce temperatures in excess of 110 degrees C, (230° Fahrenheit). Preferably, introduce a limiting switch to shut off the current after a given time, or a thermo relay.

Group Exhibits

In some areas the local science fair is combined with a Congress. Here the student is required to explain the exhibit and lecture on the work done. However, in the National Science Fair the exhibit, not the person, is judged. What you personally know about your subject is not a part of the judging procedures. Hence you need not cram or memorize anything. You are just out for a good time which should prove educational as well.

Only exhibits by individuals are allowed in the National Science Fair. Group exhibits are not admitted.

Some of the local fairs are set up to judge separately the exhibits made by boys from those made by girls. Awards of equal value are made, but are generally pro-rated on the basis of ratio of total number of boys' exhibits entered against those entered by girls. The National Science Fair is arranged as such a dual competition.

Although only individual exhibits are allowed in national competition, group exhibits are allowable in some local fairs. But group exhibits always are judged apart from those made by individuals.

Judging the Fair

Judges are appointed to evaluate exhibits in one group or class. All references to the names of the exhibitors or the schools from which they come are covered during the judging. The judges see only the title of the exhibit, and a list of the parts made and those purchased or borrowed. Sometimes judges are in-

formed of the average age of the exhibitors and whether they are boys or girls.

Usually at least one authority in the subject field to be judged is appointed to the group of judges. However, the judges have considerable latitude and may give greater values to some criteria, less weight to others, or substitute other criteria, if they chose to deviate from the usual procedure. Exhibits showing long range study and effort may be re-evalued on point score scale. In each case the opinion of the judges is final. All come to a unanimous decision and sign the score sheets.

Criteria for Judging

Most of the local fairs adhere to the point score system and criteria on which the National Science Fair is judged. This is:

I.—Creative Ability Total 30 Pts.
How much of the work appears to show originality of approach or handling? Judge that which appears to you to be original regardless of the expense of purchased or borrowed equipment. Give weight to ingenious uses of materials, if present. Consider collections creative if they seem to serve a purpose.

II.—Scientific Thought Total 30 Pts.
Does the exhibit disclose organized procedures? Is there a planned system, classification, accurate observation, controlled experiment? Does exhibit show a verification of laws, or a cause and effect, or present by models or other methods a better understanding of scientific facts or theories? Give weight to probable amount of real study and effort which is represented in the exhibit. Guard against discounting for mechanical perfection, limited coverage, or what might have been added or included.

III.—Thoroughness Total 10 Pts.
Score here for how completely the story is told. It is not essential that step by step elucidation of construction details be given in working models.

IV.—Skill Total 10 Pts.
Is the workmanship good? Under normal working conditions, is exhibit likely to demand frequent repairs? In collections, how skilled is the handling, preparation, mounting, or other treatment?

V.—Clarity . Total 10 Pts.
In your opinion, will the average person understand what is being displayed? Are guide marks, labels, descriptions neatly yet briefly presented? Is there sensible progression of the attention of the spectator across or through the exhibit?

VI.—Dramatic Value Total 10 Pts.
Is this exhibit more attractive than others in the same field? Don't be influenced by "cute" things, lights, buttons, switches, cranks or other gadgets which contribute nothing to the exhibit.

Suggested Rules for Fairs

The following suggested local science fair rules are issued by Science Clubs of America as a guide.

1. Exhibits on any scientific subject made by students may be entered if they are enrolled in any class from grade......... through grade 12 in any public, private or parochial school in (list areas covered).

2. A contestant may enter only one exhibit, either as an individual or in a group. All work on exhibits must be done by the individual or group. Teachers or sponsors may advise but must not build any part of the exhibit. An exhibit must not be an identical repetition of one shown by the same exhibitor or same group at a Science Fair of a previous year.

3. Exhibits must be confined to a space 3 by 3 feet or smaller. Oversize exhibits will be accepted only if proper functioning or display is impossible in the allotted space. Permissible oversize exhibits are ones like: telescopes, Van de Graaff generators, radio antennas, high voltage equipment, planetaria, large mounted specimens or skeletons and massive collections.

4. Construction must be durable; movable parts firmly attached; safe. All switches and cords for 110-volt operation must be approved variety. Each house-current-operated exhibit must be provided with six or more feet of cord, and the popular style of parallel plug. Battery-operated circuits need not be so treated.

5. Dangerous chemicals, open flames, explosives, poisonous reptiles, starvation experiments on animals must not be exhibited. Live animals must be fed, watered and cages cleaned daily. Plants must be watered.

6. Exhibitors will bring their exhibits to (place) on (date) and set up before 12 noon, then leave exhibit area. They will remove exhibits on (date) . Any exhibit not promptly removed may be destroyed.

7. Judges will evaluate exhibits between 1:00 and 5:00 p.m. immediately after they are set up. Only Judges and Fair Committee will be permitted in the exhibit area during judging. Scoring will be on work done by exhibitors, not on value of accessory equipment either borrowed or purchased. Criteria for judgment will be based on creative ability, scientific thought, thoroughness, skill, clarity, and dramatic value. Decision of the judges will be final.

8. Awards of (list awards here) will be announced on (date) at (time).

9. Exhibits will be classified as follows: I. Biological Sciences—A. Individual exhibits (Divisions: Primary, Intermediate, Junior, and Senior*). B.—Group exhibits (Divisions: Primary, Intermediate, Junior, and Senior.) II. Physical Sciences—A.—Individual exhibits (Divisions: Primary, Intermediate, Junior, and Senior*). B.—Group exhibits (Divisions: Primary, Intermediate, Junior, and Senior. Note: Primary (Pre-Kindergarten through 3rd year). Intermediate (4th, 5th and through 6th year). Junior (7th, 8th and through 9th year). Senior (10th, 11th, and through 12th year).

*National Science Fair entries will be selected from Individual Senior classifications only. The exhibits cannot be entered in more than one fair per season for competition leading to the National Science Fair.

10. Neither the Science Fair Committee, the cooperating groups, sponsors, nor (insert name of newspaper or other groups) assume any responsibility for loss or damage to any exhibit or part thereof.

➤ Margaretta Harmon *used two old phonograph disks to make an electrostatic generator. On page 66 she describes the machine she built.*

Display Ideas for Exhibits

The presentation of your project to visitors will be aided if some simple but dramatic methods of display are utilized. These will not be original with you and you will use them simply to present more effectively the original work that you do. Joseph H. Kraus, of the Science Clubs of America staff and co-ordinator of the National Science Fair, describes in the following articles some ways that you can make your exhibit easier to view and some methods of construction that may be used in exhibit building.

Getting Action into Exhibits

➤ NEARLY every spectator visiting a science fair likes to push a button or turn a crank just to see what happens. If something moves, and by so doing tells a better story than would have been the case had the exhibit been static, the exhibitor certainly deserves an extra round of applause.

Fortunately, many an exhibit is better understood if advantage is taken of sequence portrayal. Also with some exhibits it becomes possible to utilize all the space available for proper display which, without some sort of device to bring the subject matter to the fore in proper order, would become a hodge-podge.

Problems which beset the exhibitor are the production of a large wheel or turntable, without a lathe large enough on which to turn the piece, and the construction of large pulley wheels.

Cutting Large Wheel

If you have access to a jig-saw, a large wheel should offer but little trouble. Drive four shingle nails into the under side of a three-foot-long wooden plank, in such a position that the plank may be wired securely to the top of the jigsaw table, with the larger end projecting to the right. With a hand saw cut a slot for the blade of the jig-saw into the plank, then lash the plank securely to the table and bind with wire under the jig-saw and to the nails in the plank.

Directly in line with the jig-saw blade drive a finishing nail into the plank at the desired distance from the saw. This will determine the diameter of the wheel, the nail being at the center of the circle.

Draw diagonals across a square of plywood, which is to be the disk. Where the lines cross drill a hole just large enough to fit closely on the finishing nail. Push the plywood square into the operating saw until you can just drop the center hole on the nail. Now all that needs to be done is to turn the square slowly. A perfect circle will result.

Change of position of the center will enable you to cut circles of any diameter. For large holes in disks, drill a small hole near the desired line of cut, insert blade through hole, then refiit into jig-saw and proceed as before.

Friction Drive

A single hole rubber stopper pushed on the shaft of an electric motor and so mounted that the rubber will bear against the side of the disk will give considerable speed reduction. The smaller the stopper the slower the speed. If still greater reduction is desired the first large disk can be fitted with another rubber friction drive at the center, which in turn is to bear against the edge of the turntable. This part is easy. Just drill a suitable hole part way through at the center of the disk and insert a rubber stopper, then use this rubber as the friction drive for the turntable.

Non-circular Turntable

But if you still cannot make a large, true disk, or if you desire to use a triangle, square or five-sided display, you still can use the friction drive. Now you should set the motor and friction wheel against the bottom, but as close to the edge as possible for slow speeds, closer to the center for more rapid movement. Circular typewriter erasers make good friction wheels for this type of drive.

But where you need a large pulley or drum and cannot cut a satisfactory circle, draw a circle on the under side of the turntable and drive nails or wooden pegs a couple of inches apart along the drawn line. Wind the belt around this drum.

For hand driven speed reduction you can use an ordinary spool and crank. To center a shaft in the spool, scrape off a line of paint on an ordinary pencil. Immerse pencil in boiling water until it separates. Remove lead and substitute with a bent knitting needle crank, then push pencil and crank into the spool for a friction fit. If crank is to be at right angles to the line of motion use two eyelets or pulley wheels over which to pass the cord.

Small Flashers for Exhibits

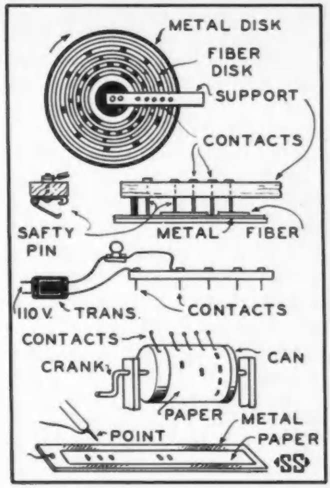
➤ Small units similar in operation to those used to produce movement in electric signs have dozens of applications for showing action in science fair exhibits. They can be employed to give direction of action to an exhibit—a 1, 2, 3, 4 effect—show flow of "materials" through a process exhibit, simulate fire or water flow, or illustrate the rotation of electrons or planets around a central mass. Similarly, the interrupted electrical impulses can be used to produce sounds, code signals, for example, or prescribe certain cycles for the operation of any controlled device in which first one thing happens, then another. Perhaps the simplest of all devices is a

strip of metal covered with a sheet of perforated insulation or paint stripes. One wire is connected to the metal base and the other is attached to a metal "point" mounted in a wooden or hard rubber pen holder. The two leads then are connected in series with the supply of current, batteries or the secondary of a low voltage transformer, and the apparatus which is to be operated electrically.

When the rod is drawn against the perforated strip it completes the circuit whenever it touches the metal and interrupts it again when it is lifted from the metallic contact by the material of which the perforated strip is made.

Because slight sparking may occur when the contact is broken it is advisable to make the perforated strip from material which will not burn. Heavy paper, fiber, hard rubber, and many other substances can be used. An ordinary paper punch can be used to make the holes or these can be cut with a sharp knife or scissors. For rough usage it is best to shellac the insulator in place. Coat both metal and paper with heavy shellac, allow to become tacky, then stick together.

It will be noted that with this arrangement the circuit will be broken slowly or rapidly, depending on speed of movement of the pointed holder against the surface of the interrupter. Such an arrangement may be used to learn the radio code in which case each letter is accurately cut into the insulating sheet, and circuit is completed to a buzzer; or blinker light for blinker practice. Letters may be set side by side to save space.



Drum Style

Where a motor drive is not suitable or where large changes in speed are needed quickly, the interrupting device can be in the form of a drum with the insulator wrapped around it. An ordinary bright tin can may be used here. Fit this with a drive, a crank and shaft for example, or a cord wrapped around one end of the can which then serves as one pulley and around a spool or other pulley attached to a crank.

In this drum arrangement you can shellac the insulating strip to the can or hold it in place by two wide rubber bands. Then you may replace it with another strip with different timing intervals.

Disk Contactor

A phonograph turntable makes an excellent unit for actuating the commutating disk; a metal record is most suited for covering with fiber, per-

forated with holes in the desired positions. The great advantage of such a design is that many different records can be prepared and can be changed on the turntable quite as easily as any phonograph record.

By an arrangement such as this the exhibitor can set up a box of lights and illustrate protons and electrons for many elements, together with their probable orbits, as demonstrated by the lights flashing in circular fashion around the center.

Contacts

Excellent contacts for use against the drum or disk can be made from small brass diaper pins. First bend these with round-nosed pliers, as shown, then attach them to a strip of wood or hard rubber. A small nut and bolt will hold them in place or the pins may be clamped between two strips of wood and the wire connecting leads may then be soldered directly to the pins.

It should be remembered that one pin should contact the drum all the time. In the case of the drum this may be located at either end. The preferable position for this grounding pin in a disk-operated flashing unit is near the center.

For safety, make sure that all circuts controlled by such a flasher are of low voltage. Use secondary relays wherever the flasher is to handle current at pressures of more than 24 volts.

Diorama Makes Display Setting

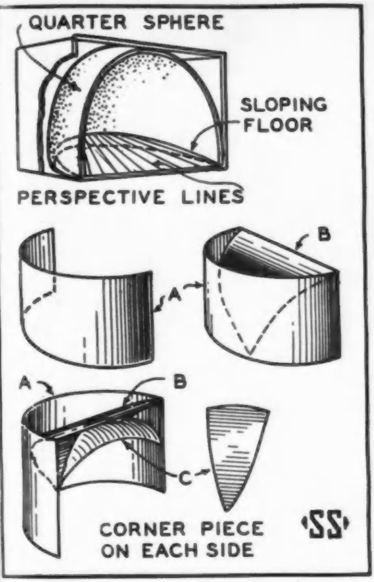
➤ THE quality of any science fair exhibit will be enhanced greatly by paying attention to the selection and treatment of the background or "stage."

One of the best for certain types of exhibits is the diorama. This gives the appearance of great distances within the confines of the space permitted for the exhibit. In a diorama no internal corners are visible, which usually is the case when looking into an unprepared box. Instead, all corners are eliminated by the use of a continuous or semi-continuous curve.

In such a miniature stage many displays take on a startling realism. Particularly is this true when showing natural habitat groups, nature scenes, models of the gigantic animals which once roamed the world, models of birds or planes in flight, models of ships, industrial plants, cross-sections of pond life, sub-soil activities, or many other kinds of models.

The extra work involved can run from the essence of simplicity to great artistry. Let us suppose that your exhibit is to be set into a cubical box. If you cut a piece of cardboard as wide as the box is tall and long enough to cover both sides and back, then gracefully curve the cardboard into the box, you will eliminate the two rear vertical corners.

But to be most effective you should also eliminate the edges where the cardboard meets the top of the box. You might also arrange the base or floor on a slant so that it establishes the line of the horizon, then provide some sort of proscenium, make use of lights, and paint the background and sky, if that is the sort of effect you intend to convey.



Dome Constructions

There are many ways to get a dome effect for the back of your exhibit. From cardboard cut a number of gores, resembling the surface of the sectors of a peeled and divided orange. Bisect each at the midpoint. Glue or tack these pieces side by side to the inside top and back wall of your box at the corners. This will produce an effective rounding after interspaces between the cardboard strips are covered with an overlay of paper pasted in place, then painted with thick paint.

More sturdy results will be had by securely tacking in gores of ordinary wire fly screening. This material is soft enough to be molded by pressure of a round wooden stick or the heel of the palm. Strips of the same material may be frayed out along the edges and inserted to round the top edges, if the same wire screen also is used for the back. Where the wire yields too much you can back it by a stuffing with excelsior.

Now dip gauze bandage, about 2 inches wide and a couple of feet long, into a thin mixture of plaster of Paris and water, run the strip between the fingers to spread out the plaster and apply directly to the inside of the wire form. Apply layer on layer of this until you have the surface well covered but not too thick because the wire support is not very strong. Smooth any irregularities with more plaster applied with the fingers. Final smoothing may be done with sandpaper after the plaster has hardened.

Use of Papier-Mache

Probably the best dome for transportable exhibits can be made from papier-mache. This is very easy when you have a large plastic ball around which to fashion the papier-mache.

Or you can pile up a mound of sand, moisten it with water so it will hold its shape, then spin an arc cut in a wide piece of cardboard or wood around the mound to produce a half sphere. But if none of these things is available you still can lick the problem by tying an old bedsheet loosely over the mouth of an ashcan, then mold the material on the inside of the sack.

For papier-mache, dip strings of newspaper or better yet, paper towel into a mixture of equal parts by volume of ordinary kitchen flour and water to which a teaspoonful of 5%

carbolic acid wash or similar antiseptic solution has been added. Do not use straight carbolic acid. Casein or other cold water glue may be used instead of flour.

Let paper soak a while until it is perfectly limp, then lay the strips criss-cross over each other until you have piled up 12 to 24 thicknesses. Let dry thoroughly, then cut to the desired shape and sandpaper the edges.

Cut the base for your exhibit to fit the curve. Front edge should be flush with the bottom of the box, back edge should be elevated. All square or rectangular objects — ships or other structures—should be built to conform to the perspective. Designs can be carried on to the background by painting on the dome. Objects in the sky, like clouds, birds, etc., should be suspended from wires hidden by the objects.

Make a proscenium of wood or cardboard, back it with lights and attach to your exhibit. If the lamp overheats any part of the display, drill a few ventilating holes through the top or use a lamp of lower watt rating.

Miniature Dark Room for Exhibits

➤ PHOSPHORESCENT and fluorescent materials to be appreciated fully must be seen in a perfectly dark room. Stroboscopic effects, some high frequency experiments, certain light, photographic and X-ray demonstrations also show up best only in the dark.

Because exhibition space is limited at science fairs a small dark "room" probably offers the best system for viewing the aforementioned exhibits. The unit here described needs no great construction skill, can be made quickly and is inexpensive.

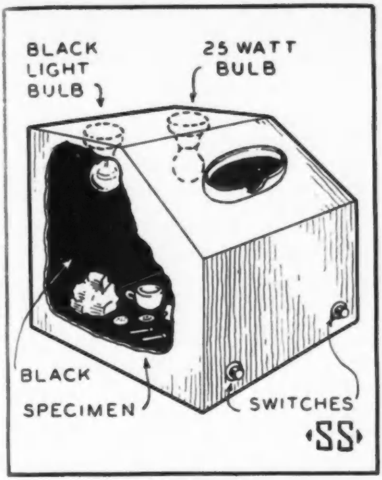
First procure from your grocer a well-made square wooden box into which the exhibit will fit. The maximum measurements should not exceed the space limitations for your own fair. Draw a line about midway across the front and top. Where these lines reach the sides draw a connecting line, producing a diagonal mark. Saw off the corner of the box, making sure that there are no nails in the way.

Make a sort of trap door from the wood thus removed. Preferably hinge it in place. Lock it with padlock or small hooks, screw or eyes. The purpose of a hinged cover is to allow access to the interior to arrange your exhibit.

Protection

With keyhole or fret saw cut a hole 4 inches wide and 2 inches high in the center of the sloping lid. Be sure to smooth the edges of the cut with wood rasp and sandpaper. Surround the opening on the outside with a firmly mounted cardboard, plastic, wood, metal or similar eyeshade, indented for the nose of the observer. Make sure that the edges of the shade are not sharp. One way to protect the face of the spectator is to straddle the top edges of the eyeshade with a split strip of small rubber tubing.

To split the rubber tube, clamp a sharp penknife at an acute angle in



the jaws of a vise. Have the blades extend over the vise just far enough to enter the bore of the rubber tube. Make a small longitudinal cut in the end of the rubber tube, straddle cut around the knife blade, then pull on the end of the tube. This will give a straight split along the entire length of the tube.

Line the inside of the eyeshade with black felt, velvet or black blotting paper. Make material wide enough so you can lap it slightly over the outside edge. Shellac or rubber cement will hold the lining. Apply shellac or rubber cement to the free edge of the eyeshade and to the inside of the rubber tube. Wait until parts become very tacky. You may have to give cloth a second coat. Then, without stretching, snap tube into position, cut it to length to make a tight joint.

In a well lighted room, or preferably out of doors, peer into your small dark room. Do not expect it to be pitch black just yet. Pay attention to those places where most of the light enters, for extra treatment. You can cover these with strips of cardboard tacked into place, except at the door, or fill cracks with plastic wood, wood putty or cord packing.

Lighting Arrangement

Prepare your lighting arrangement. If you intend to show fluorescence of minerals, paints, and the like, you might want to use 2-watt argon lamps to furnish the "black light." Such lamps may be left unfiltered, in which case there will be some visible light, or the bulbs may be placed behind special UV glass filters which exclude most of the visible light. These lamps may be left burning all the time because they consume little current and do not get hot. In this arrangement only one switch will be required to turn the white light on and off.

But if you intend to use regular UV lamps you should plan for either a two way switch or two single switches. All switches should be of the pressure-release types, that is, they function only when the finger is applied. In no case should you use bell ringing push buttons. Filament styles of black light bulbs get very hot and have a relatively short life of about 60 hours.

Cut holes for the insertion of switches, putting them in such a position that they can be manipulated easily. Line the box preferably with black velvet although black blotting paper may be substituted. For a smooth lined effect, cut heavy cardboard to fit loosely all sides, top and bottom. Lay the velvet face down on your table, put cardboard on this,

trim cloth on all sides about an inch beyond cardboard, fold over edges of cloth and cement to back of cardboard. Return cloth covered cardboard to the dark room, gluing in place, if needed.

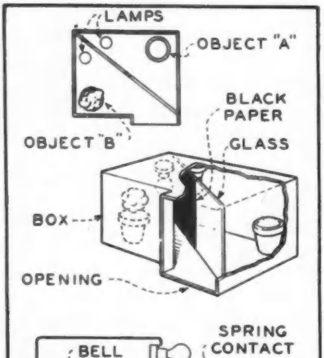
Screw lamp sockets in place. If light leaks around cover apply an extra thickness of velvet at opening. If leaks occur around hinges, cover each with a cloth strip. Finally treat surface of box in any suitable fashion.

Place box in operation and check heat produced. If things get too hot, drill vent holes in top and bottom and cover with U-shaped piece of tin to allow heat to escape without getting extraneous light.

Illusion Box for Automatic Changes

➤ AN ILLUSION box will automatically change one object into another to give an element of mystery or show progression from one event to another. It will give motion to an otherwise static exhibit. The illusion also can become the center around which to arrange other visual illusions.

With the box it becomes possible in the same position to show the growth of two pots of plants, one with and the other without certain treatments, or show an insect's wing positions in two parts of its movements. Similarly you can demonstrate protective camouflage on animals or insects by showing the scene first with and then without the creatures.



The entire construction can be completed within a short time—generally less than a day. What you put into it, or what you intend to illustrate may take much longer to arrange.

See One See Other

The change from one to the other article can be instantaneous or gradual. You could, for example, show the skeletal muscles of some creature and have them gradually obliterated by the covering skin, or you could produce the change instantly, depending on the controls you arrange for the lamps.

Essentially it consists of a square box with a window cut in the front panel to occupy about half the area. A narrow projection around the window edge will keep out much of the extraneous light. This is particularly needed if the box is to be used in a

well-lighted area. You can make the box of heavy cardboard or preferably of wood or metal. If cardboard is to be used you should provide holes for better ventilation. Size doesn't much matter. You can make the article as large as the space permits, or make it quite tiny.

Diagonally across the inside of the box arrange a sheet of clear glass, preferably only single thickness. In fact, if you can frame a thin clear plastic sheet in the space in such a way that it will remain perfectly plane at all times you will avoid double reflections. The thinner the sheet the better.

Cover half of the glass with a dull black piece of paper and paint the inside of the box with black mat paint or use black cloth.

At the corners place two lamp sockets and insert lamps to illuminate your specimens. Now introduce your two objects. When object "A" in the diagram is illuminated you will be able to see it right through the thin window. However, when this light goes out and object "B" is lighted its reflection will be seen in the glass which now acts like a mirror. If you locate the objects correctly you can make one take the place of the other or dissolve one into the other by gradually diminishing the intensity of one light and increasing the brilliance of the other.

Automatic Control

With low voltage lamps and dry cells or storage batteries an automatic control for the lights can be made from an old alarm clock and a discarded electric bell. Mount a spring contact against one of the larger wheels of the clock mechanism. This contact should be insulated from the works of the clock. Either fasten it to a block of wood or wrap it with tape first where it is to be attached to the frame.

This contact then serves to make and break the circuit to one of the lamps and also to supply current only to the magnets of the bell. To do this you must trace the wiring of the bell and make sure that the final connections are made as shown. This may mean disconnecting one of the leads either from a post or from the interrupter, depending on the construction of the bell.

The circuit to the second lamp is completed through the interrupter contact of the bell and the spring contact of the movable armature. The bell now substitutes for a relay.

To produce a dissolving effect a circular rheostat should be obtained and the leads to the lamps should be taken off at diagonally opposite points on the rheostat. As you rotate the contact more current will be fed to one lamp while the other will be dimmed. Rotation can be done by a small motor geared to low speed.

Remember that if you hope to use current from a 110 volt source you must substitute contactors and relays designed for that purpose. Do not use the electric bell type of relay on 110 volt circuits. It will get very hot.

Follow the Electrical Safety Rules for Science Fairs, given on pages 10-11, in setting up any exhibit requiring electric wiring. Many interesting effects may be contrived with clever "stage settings" and trick lighting.

Freeze Motion With Stroboscope

➤ FLICKERING lights, while annoying when you are trying to read, give scientists one of the most valuable research tools, when the flicker is controlled precisely.

Illuminated by such stroboscopic light, water dropping from a faucet or glass tube can be made to stand still in mid air, or can be made to appear to run up hill. Rapidly moving toothed or spoked wheels seem to move slowly, stop or reverse—something similar often happens in movies. Mechanics and engineers can study behavior of valves of a gas or steam engine at any position in their rapid action. The motion of the wings of birds or insects may be frozen; changes in speeds of a bouncing ball or swinging pendulum may be photographed for study. Even the hair-like cilia and flagella of micro-organisms may be slowed down so you can see how they function, when illuminated by interrupted light.

These few suggestions give student scientists plenty of background against which to dream up a vast array of different Science Fair exhibits, either of the demonstration or photographic type. Considerable variation of equipment is possible so that your exhibit can be different.

To freeze action so it can be observed, your light must flash on at exactly the right instant to illuminate that part of the action you wish to see. If the motion to be observed is at a constant speed, then the light must flash at a constant speed. If the motion to be observed is at a variable speed, then the light should be regulated by the motion to be observed so that if flashes at the same variable speed.

Many further modifications are possible, which you will discover after you start to play with this sort of exhibit for your Science Fair.

Rotating Shutter

While it is possible to interrupt current to an incandescent lamp fast enough to stop relatively slow motions, it takes too long for the filament to get hot and cool off again when working at high speeds. Therefore it is better to use non-filament lamps or a shutter arrangement. Direct current should be used, except for special applications where AC is suitable, if you want to avoid frequent blanks.

One of the easiest constructions is to mount a 32 candlepower auto headlight bulb in its socket in the bottom of a bright tin can. If you have a storage battery, both filaments can be supplied with current for greater light intensity. Still brighter light will be given if you burn the bulbs at overload voltage, say 8 to 9 volts. However this decreases life of the bulb to only an hour or so.

Cut a sharp slit in the cover or closed end of the can. The size of this is best determined by experiment, the smaller it is the more sharply defined will be the picture. Directly in front of the slit mount a disk attached to the shaft of a small toy motor. A slit in this disk should match exactly the one in the can. Paint outside of can and disk a dull black to minimize reflections. Con-

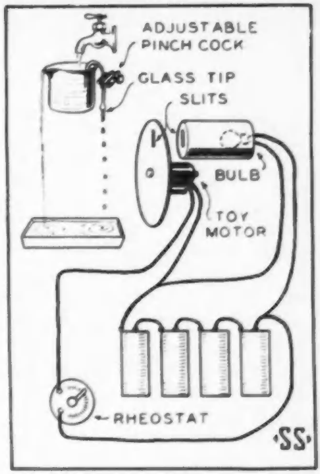
nect the motor with a rheostat for the control of speed, as shown. You can get rheostats from surplus radio parts dealers. You are now ready for your interrupted light experiments.

Running Water Stands Still

For the standing drop experiment, water should be supplied through a small nozzle at constant pressure. An easy way to do this is to fit to a rubber hose a medicine dropper or quarter inch glass tubing drawn out to a thin end. Set rubber hose into an elevated can and start the syphon, then regulate flow with a pinchcock around the hose until water breaks up into drops.

For constant pressure, punch a hole through the sides of the elevated can about an inch or so from the top or bend over a lip. As long as water issues from the overflow the pressure at the dropper end will be quite constant.

Now control the stroboscopic light by changing the motor speed. When you hit the right point of control round drops of water will remain standing in air, or you can cause them to run from the bottom into the spout, apparently.



Remember that if you plan to use the standing drop experiment in your Science Fair exhibit you will need to improvise some method for collecting the water and returning it to the top again automatically, because most exhibit areas do not have available running water and drains.

Snap Fasteners for Bearings

➤ In the design and construction of all sorts of science fair exhibits, large snap fasteners will give surprisingly good service where parts are to be connected rigidly together yet allow for speedy knock-down. The fasteners also will make accurate, free-moving bearings for cardboard, fiber or thin wooden constructions, furnish universal joints for models, or make good substitutes for pin jacks in electrical circuits.

Securing the parts in position on the models is simple and easy. Model airplane or any similar cement may be used. If such a cement is not available you can make your own by dissolving, in a small bottle of acetone, photographic film from which the emulsion has been washed. Cut the dry film into thin strips and drop into bottle. Let stand a day or two. As a substitute for acetone you may try some of the fingernail polish

removers. Some of the non-oily liquids will work.

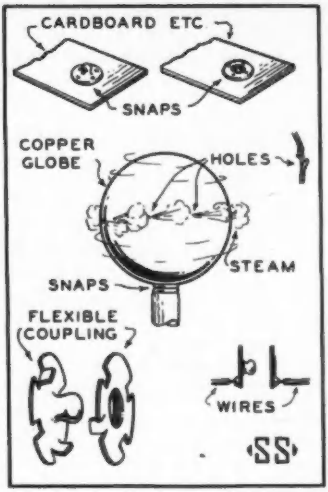
Fasteners can be sewed to the parts with needle and thread, cord, thin wire, nailed with small brads, riveted or soldered, depending on the material to which they are to be attached and the use to which they are to be put. The centers of fastener positions can be located with extreme accuracy with some of them. They have a pinhole punched through there. Thread fastener on a needle, then locate needle on the desired spot on the model. Apply cement and slide fastener along needle to desired location.

Mechanical Motions

Assume you intend to construct an exhibit board detailing some of the many forms of mechanical motions. To show mechanical advantages it is desirable that the parts move. Lever devices cut from any thin stock may be fitted with snap fasteners to serve as pivots or bearing. Such parts may be kept in motion for years without showing appreciable wear. Any part or bearing can be replaced in a matter of minutes.

Or if you want to illustrate the forces which act on any of the girders in a bridge construction you can use fasteners at those spots where movement is expected. Usually spring balances are employed to demonstrate the stresses. Round or flat elastic makes a good substitute. Fasten a cardboard index needle to that end of the elastic which will move. Put a graduated cardboard scale behind the needle.

For long rigid constructions where it is desirable to produce a knock-down unit for easy transportation,



you can apply two or three fasteners to the interlinking pieces. The same method will permit you to add a rigid arm to a lever, wheel or gear yet permit its replacement or allow it to be shifted to different spots on the model. A similar arrangement can be set up for replacement of cams of different shapes on an experimental model.

To demonstrate gear devices you can cut teeth on the periphery of your carboard or wooden wheels or cement corrugated cardboard strips against the edges. Make sure that the corrugations match where the strip joins. Use the snap fasteners as bearings to illustrate, for example, the mechanical advantages of gear trains, stop and reverse motions, and the like.

To illustrate how well snap fasteners serve as bearings, you can make a simple reaction steam turbine. Along

the equator of a metal ball punch small holes. Use a sharpened ice pick for the holes and a bath toilet flush tank float as the ball. With the ice pick bend the orifices in one direction along the line of the equator. Solder one part of the snap fastener to the base of the ball and the other half to the end of a metal rod, or wire this securely to the end of a wooden dowel. Submerge the ball in hot water until it is not quite half full. Then snap the ball on to the rod. Mount the rod so that the ball either hangs or is supported on the end; the latter position is shown. Apply heat from burner to the metal sides of the ball.

Make Universal Joints

Universal joints with slight flexibility can be made from large fasteners by cutting two notches and two tabs in each shoulder, as shown. Flexibility can be increased by loosening the fastener before cutting the tabs.

Interconnections on printed wire circuits can be changed quickly by attaching snap fasteners to the ends of the printed lines. Solder the other halves of the fasteners to short lengths of wire and juggle your conections as you desire.

This system permits you to make many different styles of testing devices on heavy cardboard, all of which may be filed away in a standard letter file. Or make a loose-leaf book with each individual page specific for a certain test and with meters, tubes and the like attached to the covers. The field for either style of exhibit, file cards or loose-leaf book, is wide open for your ingenuity and should make good science fair material.

One word of caution. Do not force apart the halves of the fasteners. Instead, insert a small knife between the halves and twist to separate, to prevent breaking attachment to wood or cardboard.

Sealed Miniature Worlds

➤ Microcosms, miniature, sealed "worlds" in which plants and/or animals live out their life spans, are fascinating things with which to experiment and display as Science Fair exhibits.

Requiring no other attention except exposure to light and healthful temperatures, when once set up the units will strike a balance after which no further great changes take place. Perhaps one plant will strangle another, or one will grow faster than the next, or a leaf will die to be replaced by another, but the microcosm finally settles down to a thing of harmonious beauty.

Easiest to establish are microcosms given over to the growth of plants, either land or water varieties. The containers which are to form the worlds in which these things will continue to live should be selected with some care. It is perfectly possible to establish plants in home preserve jars, but this kind of glass generally has too many waves and striations to give a good view of the effect.

Seek out suitable containers from your stock at home or laboratory. Specimen jars make suitable worlds. In fact, the tall types can be converted into lamps by attaching a lamp socket and shade to the lid-clamp of the jar. Then the light from the lamp will substitute for the sun needed by the plant life. Other suitable containers can be: inverted, perfectly round fish globe, broken-necked chemical flasks, cut incandescent bulbs, discarded electron or TV tubes from which the phosphor has been removed, and many others.

Prepare a suitable soil for the plants by mixing equal parts of garden loam, sharp building sand and leaf mold. The latter may be obtained from any woodland by scraping away the top surface of leaves and gathering the black substance beneath. Let dry thoroughly, then run through a medium sieve to eliminate insects which may prove injurious.

Spread the mixture on metal sheets and heat in the kitchen range to 250 degrees Fahrenheit to sterilize the soil. Let cool. Add enough water to prevent dusting then drop soil into your container, preferably through a paper tube to lessen dirt spatter on the side walls.

Plant Small Things

Be careful in your selection of plants or seeds to make sure you get types which do not grow taller than the container allows. If plants are to be used, select some similar to those which florists exhibit.

Remove plants from pots, shake off soil, wash roots, by swishing through a couple of changes of water in a pail, remove dead leaves and be particularly circumspect in your examination for diseases or pests. Grip stem and root of plant between two flat sticks and push roots well into soil. Then hold plant with one stick while you spread roots with the other. If you cannot reach the side walls because of a small neck, you can make suitable planting tools from discarded coat hanger wires. Strike the ends with hammer to flatten, if need be, then bend to reach desired spots. Lay some moss gathered from trees or woods on the surface to give a green "lawn."

Apply water to the soil through a tube. If side walls of the glass have been muddied, direct the hose against the walls. Be careful not to water too much for this will result in constant, heavy condensation on the side walls. If you slip on this detail, hang a strip of cardboard four or five inches long down into the mouth of the container. This will stimulate air circulation and tend to dry the soil.

Let the things grow for 2 or 3 weeks, then preferably on a bright morning, seal the container tightly. Give plants sunshine daily. There is your microcosm with its contained rain, food and plant growth.

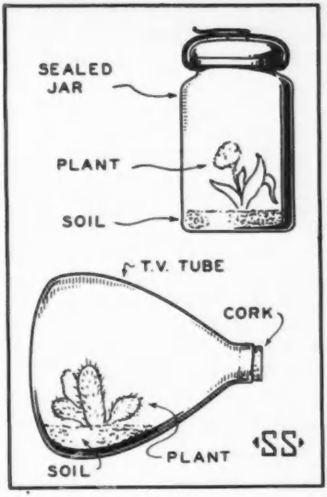
Plants may be grown in odd and unusual containers by conveying the seeds into the glass with the water. In this way the seeds will remain close to the surface instead of being buried at the bottom, which would be the case if they were introduced with the soil.

In each case, the soil requirements of the living plant should be exam-

ined. For cacti use more sand or add small stones. Also a small quantity of lime and bone meal will do no harm here. Water should be added sparingly.

Aquarian Microcosm

A similar arrangement can be made for fish. Put some swamp mud into an aquarium which you can seal. Cover surface with sand. Introduce plants as described before. Use low growing aquatic varieties. Allow plants to become established. Introduce several pair of small tropicals, wait a month or so, then seal the microcosm. Study will show that an optimum number of fish and plants will vie for the "lebensraum." This may give you an opportunity to study or plan a report from one of many different self-evident angles.



Making a Star Projector

➤ The splendor of the heavens can be imitated when mechanically projected on the inside of a dome-shaped area representing the sky. In a planetarium this is quite complicated because the movement of the planets across the skies must be indicated. Leave out the planets, and the problem becomes more simple. You can construct, then, a star-dome combination called a stellarium.

Some of the ideas in such a construction can be adapted to other uses in exhibits and displays.

The construction of the projector itself can be quite simple. However, the proper locations of the stars will take time and exacting devotion to the task if the finished instrument is to be used for instruction. The dome may be small or large. Many different thoughts will come to the minds of student scientists. Valuable contributions can be made in the increased use of such projectors in the home, school or science club laboratory.

Experiment First

Many methods for making the projector may be devised. Tin cans may be used. One easy way is to dip a 500 to 1,000 cc flask into a can of black auto lacquer. If you must shake the can or stir the contents be sure to wait until all bubbles have vanished from the surface of the paint before you dip the flask, otherwise you may find yourself projecting a lot of stars

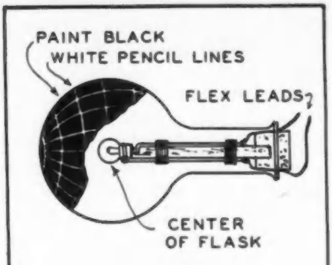
which do not exist. Let lacquer dry thoroughly, then dip again.

To mount the socket for the bulb, drill a quarter inch diameter hole partly into a cork which will fit snugly the mouth of the flask. Use an ordinary drill with cutting edges dulled slightly by rubbing with a carborundum stone; turn drill slowly. Or use a cork borer. Insert a length of quarter inch wooden dowel into the cork. Make dowel long enough so that, when a socket is affixed to the end, the filament of the bulb inserted into it will come as close to the center of the flask as possible. This position is determined easily by measurement.

The socket is a Christmas tree series-light-chain replacement unit, available from the ten-cent store. Or you can use a good socket from an otherwise useless series chain. If the surrounding plastic shell is too large to permit easy entrance through the mouth of the flask, or likely to cast a disturbing shadow, put socket on hard surface and strike lightly with a hammer to break the shell. Do not damage the metal parts.

Attach the socket to the top of the dowel by whittling away a bit of the wood at the end for passage of the socket's center connecting wire. Adhesive tape will hold the socket securely; wrap tape around pigtails of socket. Twist two longer flexible wires to the bared ends of the pigtails and cover each with tape. File grooves in the cork for passage of the wires.

The bulb should have a small straight filament. Non-lens types of 1½ volt flashlight bulbs are good. Some 6-volt bulbs work well also. You will need to try several for best



results. Current can be obtained from dry cells of toy and bell-ringing transformers. If voltage is too high, use a rheostat for further regulation.

Stars are produced by scraping tools made by breaking heavy sewing or darning needles to different thicknesses, about as follows: Select four needles of the same size. With pliers break off the very point from one needle. Break another through its thick shank. Then select a different spot on the taper leading to the point of each of the other two needles and break, thus to give four thicknesses, each to correspond with stars of relative brightness. On a hand carborundum stone or emery cloth grind broken ends to very slight point; then grind sides to produce a chisel end on each needle. Points prevent slippage, chisel edge serves as the scraping face.

Set each needle into a suitable handle. Use pen holder or the rubber end of a pencil, pushing needle into the rubber with pliers. Best is a small jeweler's clutch-type screw driver.

Making Stars

Turn on the light inside the flask. Make sure it shows black all over, and no light escapes. Any pinhole spots can be corrected with daubs of paint. With a star map or illustration before you, set point of a needle approximately at the very bottom of the flask for North Star position. Twist tool between the fingers to scrape away the lacquer. Approximate in the same manner the other stars of Ursa Minor, the Little Dipper. Don't worry if this is not exact just yet.

Darken the room and see how the projection looks. If stars appear like crescent moons your bulb is not the correct one, so change for a shorter, straighter filament type. Note particularly if stars are in correct arrangement or if projected in reverse order. If latter is the case, you will have to correct them on the flask. Make a few tests like these to establish technique, then cover all cleared spots with daubs of lacquer.

Cut a template of stiff cardboard to fit closely the side of the flask. Mark off the template in ten-degree units. Set cardboard against the flask and use as a guide for marking on the surface with a white fingernail pencil dipped in water. Circular marks are easy if the flask is rotated while the pencil is held against it.

Use a star map or other guide so that you can locate the stars properly. You can mark with the wet fingernail pencil, then use the needles for puncturing the lacquer coating.

Attach the cork to a hinged, weighted base. Arrange a suitable stop so that angles may be varied.

Best surface against which to project is a dome. You can design an umbrella-like construction or use cardboard strips pivoted at the center and spread fanwise. Or use a wire and plaster of Paris dome similar to those constructed for dioramas.

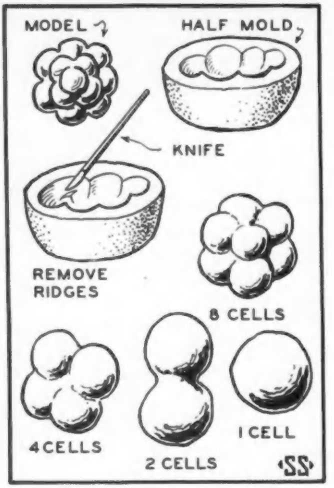
To get motion, rotate the projector by hand. Or couple with a toy motor, or pulleys and hand crank, but be sure that the coupling will allow you to tilt the unit so that you can see those stars which our neighbors down south are viewing nightly.

Making Molded Displays

➤ A COMPLETE series of papier-mache or clay models of successive stages of any event, for example, showing mitosis in a cell, twig or leaf growth, or how a single cell develops to the morula or gastrula stage, can be made speedily and economically using only one mold instead of many.

The trick is to do the casting in reverse, filling in and obliterating the marks of the major mold instead of making molds for each stage. Hundreds of models of different sequences can be made in this way, the two cited above being chosen merely as examples.

The usual method is to make a separate model of each stage from modeling clay, plaster or other material; cast a mold for each stage;



then fashion the papier-mache or plaster and finally paint to suit. While this method is well suited to commercial production, it represents a lot of molds which become useless after the first sequence is made, if only a single exhibit is required.

In the simplified procedure, one of the later stages is modeled, then the marks are obliterated to arrive at an earlier stage in the sequence. Thus the mold is doctored up and made smaller as the work progresses.

Start With Last Stage

To make one of the examples given, you should start with the morula or mulberry stage, preferably first fashioned from modeling clay. An easy way is as follows:

Roll a piece of clay to form a solid cylinder about an inch in diameter, depending on how large you want to make your model. Cut off the end, then cut the clay into equal lengths, each an inch long. Roll each portion between the palms of your hands into a ball, then put aside.

Work another batch of clay into a ball about six inches in diameter. Now you can cut this in half, if you propose to make only half-models suitable for backboard or table display, or work with the complete ball. Cut each of the inch-small balls in half and slap them against the large ball, pressing one against the other to distort slightly the sides of the smaller balls. They will then appear as in the typical mulberry stage so often seen in your studies. A sharpened wooden stick and some pellets of wet cotton will smooth any defects.

Push a nail to which a string is attached well into the clay model. Carefully suspend it by the string from some overhead support so that it will hang about two inches from the bottom of a straight-sided, well greased pot, larger than the model itself by at least a couple of inches all around.

Mix plaster of Paris with water to the consistency of thick cream and pour into the pot until it comes to the halfway position of the clay model. Push four marbles to half their depths into four different positions any place outside the model. These will become the keys for matching the halves of the form, should this be needed.

When the plaster has had a couple of hours to dry, remove the marbles. Coat all the exposed plaster with several applications of soap suds, then cover the rest of the model with an-

other batch of plaster, just as you did first. Let it dry for a couple of days, then separate the halves and remove the clay, piecemeal, if necessary.

Depending on the depth of the under-cuts, the mold must sometimes be cut into three or more segments. This may be done with a saw or by laying cutting wires on the model itself and pulling through while plaster still is soft enough to cut.

Papier-Mache

Cover the inside of the dry plaster form with moist tissue paper. (Toilet or face tissue will do.) This is to prevent the papier-mache from sticking to the walls. Tear newspaper into one-inch-wide strips about five inches long. Soak several pieces in water, then remove, place them on large newspaper sheet and brush one side of the wet strips with a paste made from flour and water, or use cold water glue made as directed on the package. Lay strips criss-cross into the form, glue side down, and press well into all crevices. Continue until you have built up a wall of paper about a quarter-inch thick. Repeat with the other half-model, if desired. When dry, remove the model. Sand edges and glue the halves together if this is the plan for the exhibit.

With this stage complete, look inside the mold. You will find that you need to remove some of the ridges. This can be done by scraping them out with improvised tools, a grapefruit knife, for example. Or some parts may need to be filled in to produce the later gastrula stage, for example, or the smaller earlier stage of fewer cells.

Filling may be done with plaster of Paris to which a small quantity of cold water glue has been added. The glue keeps the plaster soft longer and permits working with a pasty mass instead of a hard surface. The glue repair job may take a day to dry. Thus, by repeated filling in, recarving and fashioning, you will reach the earliest, single cell stage. Then throw away the mold. It has served its purpose.

Reading Reference

For exhibition ideas:

American Museum of Natural History, Guide Leaflet Series, especially
No. 53—The Story of Museum Groups, by Frederic A. Lucas.
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No. 58—Preparation of Birds for Study, by James P. Chapin.

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Educational Work in Museums of the United States, Development, Methods and Trends, by Grace Fisher Ramsey, H. W. Wilson Co., N. Y., 1938. (Contains an extensive bibliography).

Company Museums, by Laurence Vail Coleman, American Association of Museums, Washington, D.C. 1943. (Contains a list of such museums.)

Field Manual for Museums, by Ned J. Burns, National Park Service, U. S. Government Printing Office, Washington, D. C. 1941.

For electronics help:

American Radio Relay League Handbook, A.R.R.L., West Hartford, Conn.

Electronic Control Circuits, Advt. Dept., Sylvania Electric Products Co., Emporium, Pa.

Handbook of Industrial Electronic Circuits, Markus and Zeluff, McGraw-Hill, New York.

Exhibit Ideas from Museums

In various parts of the nation there are museums, small and large, many of which either specialize in science and technology or have sections which contain science exhibits. Some of these are for educational purposes with the primary objective of serving schools, others are historical, some are industrial, and others specialize in natural history. The national organization of museums is the American Association of Museums with headquarters at the Smithsonian Institution, Washington 25, D. C. Dr. Laurence Vail Coleman is director and with his permission the following excerpts from one of his books and from the MUSEUM NEWS, *association membership publication are reprinted, with acknowledgement to professional museum workers and the suggestion that when possible their help be sought by younger exhibit makers.*

About Science Museums

by LAURENCE VAIL COLEMAN

Excerpt from MANUAL FOR SMALL MUSEUMS, Chapter XXIX.

➤ THERE ARE two quite different interests in science; one focuses attention upon the names and classification of things and the other upon the significance of natural phenomena. The former interest has predominated in museums of the past, but the latter is now well established as an equally important concern. As will be seen, these two interests may find expression differently in study collections on the one hand and in exhibits on the other.

As a basis for shaping the growth of both collections and exhibits, definite determination of geographic range is necessary. Limitations of space and means usually require that a science study collection follow the lines of a specialty in order not to be be superficial and relatively useless. On the other hand, exhibits must be rather comprehensive, though not necessarily exhaustive, in order to meet the needs of educational work.

Study Collection

The study collection is called upon to assist in identifying specimens found locally and to furnish materials for research. A local collection is adequate to the first purpose, of course, and the work of forming such a collection in any branch of science offers ample opportunity for original investigation. Few small museums find occasion or facilities to undertake anything more ambitious. Efforts should be made to extend the collection in directions for which the local region offers unusual material. Almost every locality is a good collecting ground for some specialty, and by taking advantage of opportunities, a museum may add greatly to the importance of its series and also prepare itself to assist other institutions.

Because of the character of museum materials, the research worker who is drawn to a museum—be he a

member of the staff or a visiting student—is likely to be one whose interest is primarily in classification and nomenclature. Such investigators usually carry on some collecting in connection with their studies, and material so acquired ultimately becomes a part of the study collection if the worker is connected with the museum. In this way the collection naturally becomes an instrument of identification, and the usefulness of the material is enhanced by its use. Given the interest, the development follows.

Thus, so far as the study collection is concerned, local scope, treatment of all the natural sciences, and emphasis on collecting and taxonomy are to be expected.

Permanent Exhibits

The exhibits are called upon to deal with natural history in such a way that a general view of the more important facts and laws of nature may be gotten from them.

Therefore, they are required to be much more than a synopsis of the study collection; they should convey an understanding of the work of natural forces as manifested by inanimate objects and living creatures in the out-of-doors. This is a difficult undertaking, and one which might absorb the entire energies of a large institution. But however modest they may be, exhibits may be designed to present the same whole—slenderness of resources limiting elaborateness of treatment rather than range of subject matter. The following outline suggests the essentials of permanent exhibits:

EARTH—origin, geologic forces that have transformed it and stages through which it has passed, materials and structure with special reference to locality.

FOSSILS—character of fossils, evolutionary, local fossils.

BIOLOGY—lifeless and living matter, the cell, simple organisms, tissues, elements of physiology, embroyology and heredity.

PLANTS—plant structure and classification, synopsis of local flora.

ANIMALS—animal structure and classification, synopsis of local fauna.

Mounted or preserved specimens are used extensively, but pictures and models are necessary to bring out certain subjects. Groups are usually employed; they are ideal for synoptic presentation of such subjects as life associations—plants and animals of the desert, the forest, the ocean, fresh water and other environments.

Thus in the permanent exhibits wide geographic scope, treatment of all the natural sciences, and emphasis upon principles are appropriate.

Temporary Exhibits

Temporary exhibits afford opportunity to touch here and there upon subject matter which lends itself rather poorly to presentation in the permanent exhibits, chiefly because it requires detailed elaboration. This matter is *applied* science—science in relation to man. Popular interest attaches to all branches of this field and treatments of them may be of great practical usefulness.

Personal hygiene and public health are especially fruitful fields. Exhibition material that is appropriate for

temporary installation may be secured from national organizations interested in cancer, tuberculosis, child health and related subjects, and museums may contribute largely to health education by interesting themselves in such possibilities. Science as applied to the farm offers a further series of opportunities in connection with which the U. S. Department of Agriculture is invariably ready to cooperate through its local agencies.

The temporary exhibits also afford means of interpreting the most important current events in science. An eclipse, an earthquake or a discovery may be explained in a simple exhibit which may actually be more effective because of any informality or crudeness it may have in consequence of hasty preparation.

Living plants and animals are often used to advantage as temporary exhibits. A certain western museum has two tables near the entrance—one for local plants and the other for local animals. Every week a new living individual is placed on each table in a pot, tray or cage as required, and nine persons in ten who enter the museum inspect these two exhibits and read the typewritten labels carefully. Quite like this plan is that of a table upon which cut or growing wild flowers are shown in continually changing combinations as the season progresses. Living insects may also be shown. From such installations it is but a step to outdoor exhibits.

Science Exhibition for Traveling

by William A. Burns

Curator, Department of Education, American Museum of Natural History, New York.

➤ The problem of planning science exhibition for traveling is primarily one of determining community or school needs and then of applying the best we have in talent and imagination to the best we can obtain in materials that fit our budget and befit the standards of the American Museum of Natural History.

The entire problem may be divided into six areas: (1) the selection or determination of subject or theme of the exhibition, (2) research within and without the institution, (3) research application or preparation of materials, (4) presentation that includes arrangement, color and labelling, (5) manufacture, and (6) the area of distribution.

I would like to take up each area, with examples of exhibitions we have accomplished, to point out the problems that beset us at the time, problems that are common to all museum staffs in the preparation and manufacture of traveling exhibitions.

The selection or determination of subject or theme is dependent on the needs of the school or of the community. It may also differ as to geographical, cultural or industrial location. In short, one traveling exhibition may be suitable for a given area but may be unsuited for another. It

is, therefore, necessary to be familiar with the characteristics of each community before making selection of the subject or theme of the exhibition.

In cosmopolitan New York, there is no immediate community. The community is composed of New York's multi-million population, supplemented by its daily influx of thousands of visitors. Therefore, the large museum in a big city must make the determination of subject or theme on a basis of current general interest or upon a realized need of its vast community. The smaller museum in a city or town does not have this problem to the same degree. In this respect, the small museum is more fortunate in that it is able to make a survey of the needs of its clientele and to satisfy those needs within the limitations of its own budget and available personnel.

A striking example of the satisfaction of needs as expressed by our own community was a situation that developed immediately after Pearl Harbor in 1941. If you recall, there was a great fear, particularly in metropolitan coastal areas, that cities would be bombed by the enemy—German or Japanese—depending upon which coast the cities were.

In New York, the anxiety of mothers and fathers for the safety of their children was reflected in a Board of Education order forbidding the school children under its care to venture out into city streets during school hours. Before this order, the American Museum had been host to thousands of children visiting the institution in classes, accompanied by their teachers and a few convoying parents. Since the Board of Education forbade the children to come to the museum, we thought that the museum ought to go to the children.

One of the exhibitions that we made at that time was Man and His Tools, a series of cased exhibits that showed how man progressed from stone implements to bronze, from bronze to iron and from iron to steel. The exehibition was based on the need of children to comprehend that the civilization in which they found themselves was not the be-all and the end-all of culture, that it was merely a progressive step in a long history of evolving civilizations. Modern man tends to forget the origins of things—simple tools like a hammer, a screw driver, a knife, a pair of pliers, a safety pin. In order that he may properly orientate himself, that he may place himself and his physical and social environment in their proper relation to other time-periods, it is sometimes necessary to acquaint or to re-acquaint him with his beginnings and subsequent development through the ages. This point had been realized by the metropolitan teachers and the department of education of the American Museum had also been aware of it. Here, then, was an opportunity to meet a need of the community, as represented by the school and its teachers and to fulfill a basic obligation of the museum to help others to interpret common objects in terms of their daily lives.

The exhibition presented a problem to the department that required most of its research in the museum. The curator of prehistoric archaeology was consulted, conferences were arranged, and the exhibition was

divided into its four logical parts—the Stone Age, the Bronze Age, the Iron Age and the Steel or Modern Age. The department of archaeology, in cooperation with an education department representative, selected out of each Age, significant artifacts, their method of manufacture, research bibliographies, and the actual loan of materials that could not be duplicated in the education department's division of manufactures. Since the artifacts of the Bronze and Iron Ages were so valuable, duplicates were made, using substitute materials.

When research had been done, the artifacts and duplicates had to be assembled. The entire Stone Age cases were filled with actual eoliths, hammers, arrow heads, scrapers, adzes and awls. In the collection for the Bronze Age were celts, needles, bronze safety pins or fibulae, ornaments, razors and spear points. Imaginative drawings were obtained, showing the use of these objects in the everyday life of the people who made them. The entire Bronze Age collection had to be duplicated and "antiqued" to look the same as those dug out of mounds or middens. Sheet metal, shaped with saw and hammer, then painted with verdigris green, served as Bronze Age razors, needles and ornaments.

When we came to the Iron Age, it was necessary to duplicate heavy iron shears, chisels, spear points, anvils, adzes and other basic tools. This was done with wood, finished to resemble the rust-encrusted originals in the musem. Enlarged photographs of drawings, showing the use of the tools, were also obtained.

The Modern or Steel Age was easier to complete. We visited the local five-and-ten-cent store and bought drills, hammers, pliers, punches, scissors and other common adaptations of basic tools, together with photographs of their use in modern industry and in the home.

Now we had finished the first three steps—selection, research and preparation of materials. The next step was to fix arrangement, to choose the colors that would best fit the subject and to prepare labels to assist in the interpretation of the artifacts and the illustrations.

Arrangement was made on a progression of tools as evolved by man, from rude hammer stones to awls, scrapers and adzes. This principle was carried out in Bronze, Iron and Steel Age exhibitions so that the viewer could find, in the same physical location, similar tools as used in different ages.

A special problem presented itself. These traveling exhibitions were to take the place of the children's visits to the museum. They could not successfully convey their message in miniature form, so they had to be rather large. Each case, covering each Age, would contain a number of objects, pictures and labels. The staff conferred and then decided that each of the Ages could be presented by two folding cases, large enough to command classroom attention. Each case was made in three sections—a middle panel and two folding cases opening to two segments each.

After the style and size of the cases were determined, the question of color had to be met. Since the theme of

the exhibit was "Man and His Tools," it was thought that red earth color would best exemplify man's close relationship to the earth and its products. Psychologically, the rust-red earth color was sound and it also resisted finger marks and soilage.

Labels were of two kinds: large cut-out letters nailed to the case and descriptive matter typed sharply and clearly in half-inch type on a label typewriter. Larger labels could be read from the back of the room and smaller letters could be read four or five feet away.

The department of education of the American Museum is fortunate in that it had its own combination carpenter shop and artist's atelier. Here the planning and manufacture of exhibitions is done. The carpenter, together with the staff, planned the building of these portable cases with the following desirable elements in mind; portability, strength, attractiveness, and safety to those using them.

Construction was begun with clear white pine stock as the basic material. Joints were rabbitted, reinforcing corners were used. Objects, when cases were completed, were wired strongly to the Upson board backing. Since all objects were to be wired, it was decided not to face the cases with glass or lumarith. First, glass presented a hazard to school children, since they sometimes assist teachers in moving cases up or down stairs or from one room to another. Second, glass would add to the weight of the cases. Third, the use of lumarith increased the unit cost of each exhibition case and in an exhibition made up of four panels and sixteen segments the rise in costs would be considerable.

When the cases were completed and painted, the objects were wired to the backing, labels were fastened, letters nailed on and the photographs mounted. The exhibitions were then ready to travel.

During the war years, distribution was made to the schools by means of the education department's fleet of trucks. When the children returned to the museum for regular education programs, the distribution of the exhibition decreased. There has been, however, a small but steady distribution to schools, other museums and libraries, schools being serviced by trucks and out-of-town agencies by railway.

During this time, seven years to be exact, the exhibitions have shown their ability to stand up under a variety of travel and exhibition conditions. Recent inspection showed them to be in almost perfect shape. Little structural damage has occurred and what repairs were needed were done quickly with a screw here, a nail there and a brushful of paint to touch up scratches. One valuable aid we found was to mix more paint than was needed to have for later repair.

Other exhibitions have been constructed along the same lines: an exhibition on atomic energy, an exhibit showing how the American Museum of Natural History develops an educational theme for children (this exhibition went to Paris last year, and to my knowledge, is still travelling around France, the Netherlands and Scandinavia).

All traveling exhibits have the same characteristics: strong initial construction, lack of glass or lumarith fronts if possible, colors below the middle scale to avoid soilage, hard finish gloss paint or enamel to avoid or minimize scratching, and the incorporation of materials of construction as light in weight as is consistent with structural strength.

We do not send out materials that have be shipped in glass cases. On rare occasions, our materials are exhibited under glass but the cases belong to the recipient and therefore present no difficulties to us other than suggesting the manner of arrangement or lighting. With the exception of our small loan cases, which are self-lighted, the exhibitions depend on the lighting facilities of the borrower. Again, weight and cost are reduced.

Finally, shipping to local areas is done without crating since the care with which our own men handle our exhibitions obviates the necessity of expensive and excessive protection. When cases are handled by commercial haulers or railway express they are carefully crated en route.

Summing up, it seems to me that the problem of planning science exhibitions for traveling resolves itself into the factors I mentioned at the beginning of this paper—that we must know what our community wants in the way of exhibitions that can be transported, that we must know how our own resources and skills can be adapted to meet community needs and that we must then apply the best we have and can afford in talent, imagination, materials and construction to produce exhibitions that will work a two-fold good — educational benefit to those who receive and use them, and credit to the institution that has realized its educational responsibility in making them available.

(Paper read at the Annual Meeting of the American Association of Museums, Chicago, May, 1949.)

Plastic Cases for Bird Skins

by Catherine B. Paris

Curator of Education, Washington State Museum, Seattle, Wash.

➤For almost twenty years, the Washington State Museum has been sending study collections to the schools of the state. Every spring, there is great demand for help in teaching bird identification. Mounted birds cannot be sent safely through the mail, and so bird skins are sent. At first, these were put on a wooden cradle and covered with celluloid. It was difficult to fasten the skin firmly, the whole bird was not visible, and the celluloid clouded in a comparatively short time. Then celluloid tubes with wooden ends were tried, but the celluloid is so flexible that it bent and broke with consequent damage to the skin. The problem was to encase the skins so that they could be shipped safely and be handled freely by the children without damage, and yet to have perfect visibility on all sides. Plastic offered a solution, and the following is the method we have de-

vised. Two birds so encased have been in use for almost a year with no apparent damage.

Start with a flat piece of plastic a little longer and wider than the bird skin. We have found that the best visibility is achieved if the bird is laid on its side, but the condition of the skin will dictate the position. The size of the piece of plastic will determine the thickness necessary for rigidity. Care must be taken that all edges are straight and smooth, and that all corners are exact right angles. On this base fasten a "pillow" to support the head of the bird. There are a number of adequate solvents, but we have found trichloroethane most satisfactory. I will call it "cement" for brevity. Place the bird skin on the base and mark the position of the head on the *outside* of the base. A wet, red wax pencil makes a mark which can be seen easily and which rubs off without damage to the plastic. The pillow should be thick enough to fill the space between the plastic base and the head of the bird, and large enough to give the head firm support. Pour enough cement into a glass dish to cover the bottom of the dish, and soak the pillow in this for three minutes. Place the soaked surface on the base in the position marked for the head, clamp tightly in a vise or with clamps covered to prevent marking the plastic, and leave untouched until it is thoroughly dry—about 12 hours. The trichloroethane dissolves the plastic and it dries as one piece if air is completely excluded by pressure.

The bird is fastened to the base by impaling it on needles set in the base and the pillow. We use phonograph needles as they are sharp enough to penetrate readily and yet have enough substance to hold heat. They must be cut short enough so that they do not protrude through the bird. Place the bird on the base and mark on the outside of the base positions for two pins through the body, and one in the pillow through the head. Holding the pins in ordinary pliers, heat the blunt end red hot in a gas or alcohol flame and press quickly into the plastic at the points marked. Be sure to heat and set the blunt ends of the pins. The plastic will set immediately and hold them fast. Impale the bird firmly on the pins.

For the canopy over the bird, 1/16 inch plastic has been found thick enough for any bird encased so far. The bend gives this thickness rigidity, and if the plastic is thicker it requires more heat to soften it adequately. Use a square piece the length of the base and slightly wider than required to go over the bird from one side of the base to the other. Place plastic in an oven with controlled temperature and heat to 225 degrees, or heat in a pan of scalding water. Do not let water run into the pan on the plastic or it will cause ripples. When the plastic is soft, bend it quickly over a smooth wooden dowel with a diameter slightly less than the width of the base. It must be slightly smaller to allow for some spring back. The canopy should touch the bird to hold it down firmly on the base but not compress it, and should extend about one-eighth inch below the base to act as runners protecting the base from scratching. Soak the sides of the base, first one and then the other, the same way as the

pillow. Place the canopy down over the bird and clamp along cemented sides. If the vise jaws are not as wide as the case, place smooth, heavy board along the sides and clamp all together tightly with even pressure. Leave untouched for 24 to 36 hours. Cut two pieces of plastic the same thickness as the base to fit over the ends. Soak the ends of the completed assembly in cement. Care must be taken not to soak deeply. Stand case on one end piece, place the other end piece over the top and hold it down with a heavy weight. A piece of steel weighing about four pounds gives adequate weight and is easily balanced to give even pressure. Leave untouched for 24 to 36 hours. When the case is thoroughly dry, buff off any outside marks and polish by hand with anti-static wax and a soft cloth. A nylon stocking is an excellent polishing cloth. If the plastic becomes scratched or marred during the manufacture, remove the marks immediately. If deeply marred, smooth with wet or dry sand paper, grade 400 A, then with a very soft buffing wheel and plastic buffing compound.

These cases can be made with a scroll saw as the only tool, but the hand labor involved would be long and tedious. We have a small table saw, a vixen file, a hand scroll saw, and a soft buffing wheel. Ideal equipment would be a power hand saw, power jig saw, an oven with thermostatic control, a belt sander of the pedestal type, and a two-wheel grinder with one very soft and one slightly harder wheel.

We ship these cases in boxes made of plywood, fitted with trays which have compartments to fit each bird case exactly and lined with some soft materials as felt or outing flannel. Chamois skin would be the best lining, but is expensive.

As guides for developing this technique, we have found two manuals by the Rhom and Haas Company, "Plexiglas Fabricating Manual" and "Working with Plexiglas," and the Dupont Plastics Bulletin very helpful.

Points to remember are as follows:

Have all surfaces to be cemented perfectly smooth. File all saw tooth marks or inequalities flat with a fine vixen file.

Have sides to be clamped or to be held in a vise perfectly parallel.

Make sure pressure is great enough to exclude all air, but not great enough to scratch the plastic.

Do all buffing possible before the bird is enclosed. Even light rubbing creates a static charge which will lift the feathers. Use anti-static wax for all polishing after the bird is encased to decrease the danger of static.

Make the base and canopy long and wide enough. Remember that there must be room for the bill and the tail. The canopy can be filed or sanded straight after it is formed.

Locate the pillow and the pins carefully. Bring the canopy down until it touches the bird. The pins will hold it from moving sideways and the canopy must keep it from moving up and down.

Heat the plastic thoroughly before bending it. It will be very limp when heated through. It cools quickly, so work rapidly. If it is formed when too cool, lines of stress will appear on the inside, and it may even crack.

How Taxidermist's Art Creates Life-like Museum Specimens

Mounting of Animals

by Homer R. Dill

Director Emeritus, Museum of Natural History, State University of Iowa, Iowa City.

➤ During the past decade we have developed new methods of mounting small and medium-sized mammals and have found new material for use in place of preparations no longer on the market. One has but to see some of the faultlessly mounted mammals produced by our Curator Walter Thietje to be convinced that the new methods are all right.

In most cases the best results will be obtained from freshly killed animals. However, with the very small mammals it is better to place the specimen in a solution of full test grain alcohol and turpentine 50-50 after the entrails have been removed. For collecting small mammals in the field this solution is a marked improvement over sulphuric acid and salt. I have seen mammals taken from the alcohol and turpentine solution, after more than a year, that skinned out better than fresh material. The flesh thus preserved will keep for a long time in a moist condition, and the solution tans the skins very nicely.

Casting the Nose

Animals collected in the late fall or winer months, when the skins are prime, are best for mounting. One of the first steps is to make a plaster mold of the nose, mouth, and face as far back as the eyes. This should be done as soon after the animal has been killed as is convenient, although it can still be done from a preserved specimen.

Clean the specimen well. Remove the vibrassa (so-called whiskers) on the sides of the lips, which may be done by plucking them out one at a time with strong forceps, being careful to note the arrangement so that they may be put back in the natural order after the specimen is mounted. Keep the vibrassa in sealed envelopes, marked right and left, so that the preparator may know at once where they belong when the time comes to use them.

Grease the hair of the face as far back as the eyes. Arrange the lips in a natural position, pinning them in place with insect pins if necessary. Prop the head up so that the nose is in a perpendicular position. Put a piece of cloth around the head just back of the mouth to protect the rest of the head from plaster. A clay or cardboard bridge may next be put completely around the head in front of the cloth, leaving only the greased portions exposed. Mix some molding plaster and pour over the exposed part. When the plaster has set, remove the resulting mold. The grease may now be removed with a little gasoline.

We shall not be able to proceed further with the final casting of the nose until the animal has been skinned and the skull cleaned. However, as a matter of convenience in describing this process, we will assume that we now have the cleaned skull at hand. The lower jaw should be carefully articulated in its natural position. The skull may now be placed in the plaster mold, after the mold has been well soaked in hot water. Care should be taken to place the skull in the same relative position in the mold that it had in the animal when the mold was made, thus leaving a space between the walls of the mold and the skull. When the skull is in position, turn melted beeswax into the mold until all parts are full. When the wax is hard it should form a perfect nose and lips on the skull. It is indeed perfect for our purpose in that the wax shrinks enough to make the cast parts enough smaller than in life so that they will fit inside the skin of the animal when it is mounted. But for this shrinkage the cast would have to be worked down to the proper size. With a fine pointed tool or small knife, which must be kept hot, cut an opening around the edge of the wax mouth into which the edges of the lips may be placed when the skin is put in position. The nostril openings should also be enlarged enough to receive the nostril linings that are attached to the skin.

Skinning the Animal

Before skinning the animal decide upon the position in which it is to be mounted. As a guide use a good photograph from life if possible. Make an incision down the belly starting at a point near the lower end of the sternum and continuing down to the vent. In the case of larger animals, such as fox and coon, the opening may be carried on down the ventral side of the tail to a point about one-half inch from the distal end of the tail, a small pocket being left in the end of the tail sheath into which a wire may be put when the animal is mounted. In very small mammals the tail should not be split. In such cases the bone and flesh part may easily be drawn out, leaving the tail sheath intact.

Push the skin away from the sides of the openings until the hind limbs are exposed. Next work the skin up over the knee and then down the leg, leaving it attached to the body. In large animals it is possible to skin down to the last digit of the toes.

Disjoint at this point and leave only the toenails attached to the skin. In smaller mammals where the skin will not turn down over the foot, the toes may be skinned and disarticulated from an outside opening in the bottom of the foot. When each toe has been disconnected from the hind legs and the tail skinned out, the skin may then be worked back over the body to the fore legs. Skin down the fore legs to the ends of the toes in the same manner used in skinning the hind limbs. After the fore legs have been separated from the skin, the skinning may be continued down the neck to the base of the ears. Here care should be taken to keep the cartilaginous portions of the ear intact. Cut close to the skull, leaving the complete ear attached to the skin. Skin the head in the usual manner, leaving a margin of skin around the lips so that, when the animal is mounted, there will be

enough skin on the edges of the lips to tuck into the mouth opening on the modeled form. Split out the folded edges of the lips, leaving attached to the skin the part that naturally folds back into the mouth. Trim off all fatty tissue as well as the roots of the vibrassa. Remove all of the cartilaginous parts of the nose, leaving the tiny nostril linings to tuck into the nose form when the specimen is mounted. Skin out the ears, removing the cartilaginous parts intact. Salt the skin well with fine salt, applying it to both hair and flesh sides. If the solution of turpentine and alcohol is at hand the salt can be omitted. Clean the skin and hair and put the skin in the solution until wanted.

Casting the Skinned Body

As soon as the skin has been removed from the animal, place the carcass with the head attached in a position decided upon for the mounted specimen. When it has been backed up with moist sand or clay, make a plaster mold of one complete side. If so desired, the other side of the body and legs may be made with a piece mold.

Cleaning the Skull

Sever the head from the neck and trim off all of the flesh that will come away easily from the skull. Place the skull in a pan of water to which strong soap powder has been added and simmer over a flame until the tissue that is on the skull becomes completely macerated. Wash the skull under a water faucet and brush away the softened tisue. Poison with arsenic water, and dry.

Making the Artificial Body

Wind an excelsior body and neck the size and shape of the original, using the cast of the carcass as a guide. A very hard form may be produced with excelsior by moistening the material and rolling it into firm rolls and binding them down with string. These parts should be worked into the desired shape as they are bound together. Do not include the legs, but make sufficient allowance at the points where the legs naturally join the body so that, when the legs are finally attached, the completed form will have the proper thickness and outline. For smaller animals the body may be carved from balsa wood.

Modeling the Head

The skull which has on it the cast nose and lips should now be attached to a strong wire, of sufficient size to support the head firmly and also long enough to pass through the entire body and clinch. This wire may be attached to the skull by making a loop in one end of the wire and setting this loop in the brain cavity of the skull with plaster. The free end of the wire may be sharpened so that it will pass readily through the artificial body.

Before attaching the head to the body, model in the face muscles, using cotton dipped in melted beeswax. Use metal tools that are hot to prevent the wax from sticking to the tools.

Making the Legs and Tail

The muscles that form the fore shoulders and hips are not included in the body form but are to be supplied as a part of the animal's limbs. The fore limbs should be made in

four segments, and the hind legs in three parts. Balsa wood is by far the best material for making the artificial limbs. Carve out the parts so that they will fit together and form the desired outline of the leg. These parts are fastened together by passing a large wire, strong enough to support the weight of the body, completely through each one, using holes that have been previously drilled for the purpose. To have the holes in the right place and also to prevent splitting of the wood, it is best to drill the holes in the blocks of wood and then to carve the legs so that the holes come in the proper places. The upper ends of the wires should be sharpened and left long enough to clinch in the body; the lower end should be of sufficient length to pass through the feet and the base on which the mounted animal is to stand.

The tail is made in the usual manner by rolling and winding tow on a wire until it fits the sheath of the skin. When it is wound hard and smooth, coat it over with hot beeswax and rub over with turpentine. Leave about ten or twelve inches of wire on the base end of the tail form for fastening the form to the artificial body. In very small mammals, only nickel or monel-metal wire should be used in the tails. The artificial limbs may be made in two sections each, instead of four and three as is used in the large mammals.

Treatment of the Skin

A well-cured and perfectly dressed skin with clean and fluffy hair is of the utmost importance in obtaining satisfactory results in mounted mammals. Although for many years we have used a bath of equal parts grain alcohol and turpentine for holding the epidermis on a small mammal skin, we did not realize that this same bath would tan a skin perfectly as well as preserve the whole animal in a wet state. Having tried this process out on many skins, I am pleased to announce that it works perfectly on animals up to the size of a beaver.

Putting Skin Over Body

The skin that has previously been salted should be scraped free from bits of flesh and fatty tissue, all folds and wrinkles straightened out, and every last bit of oil removed, with gasoline if necessary. Wash well in clear soft water to remove the salt. Place in a bath of alcohol and turpentine and let remain for a few days or until wanted. When the skin is removed from the alcohol and turpentine it will be found to be perfectly tanned. Wash it well in a suds of Dreft, a non-soap washing powder. Dreft is better, in our experience, for fur and feathers than any of the soap powders. Soap when used on fur or feathers is inclined to leave a colorless deposit, which the chemists call soap tar. More than once I have seen taxidermists puzzled because the feathers of a bird skin would not fluff out after washing them in soap. Dreft, however, does a perfect job on feathers or fur. One should be careful that the skins to be washed are entirely free from blood. Blood mixed with Dreft makes a sorry mess of a bird skin or a fur pelt. Dry out the fur in front of an electric fan, or with a compressed-air hose.

Before the skin is put over the artificial body and legs it should be well painted with arsenic water on the flesh side. If convenient, leave the

skin rolled up in the icebox over night so that the poison will permeate it thoroughly. If in a locality where the moths are bad, the whole pelt, fur and all, may be immersed in a diluted solution of arsenic water (10 gal. water, 1 lb. bicarbonate of soda, 2 lbs. commercial white arsenic trioxide, boil well and cool before using).

First draw the skin over the artificial legs, adjusting the skin so that it rests naturally and will not have to be moved after it begins to dry. The supporting wires should come out through the openings in the bottoms of the feet. The artificial body with the neck and head attached should next be put in place. The legs may then be attached to the body by the protruding wires, which should be clinched firmly, and the tail form fastened to the back of the body in the same manner. Fill slightly around body joints with chopped tow. Sew up the openings along the belly and the tail. The joints of the legs and feet should be filled and modeled into shape with the following composition: Dextrin paste to which pulverized asbestos has been added until it is about like putty. (Recipe for Stock Paste and Cement, by Julius Freisser, The Museum News, Sept. 1, 1931.) Since all the bones have been removed from the feet, the preparator will be able to fill each toe and the adjoining foot perfectly. The wires which protrude from the bottoms of the legs should be bent to fit into the feet and brought out so they will be in suitable positions to support the legs and at the same time be concealed. After all parts have been properly adjusted, the openings in the feet should be sewed.

Do not try to keep all of the skin moist at one time. Work on one part until it is properly filled and proceed with the next. If the skin dries on the unfinished parts it will do no harm as long as it is in approximately the proper position on the form. Dry skin is easily relaxed by applying wet cotton to the flesh side.

The skin of the head should be well coated with dextrin paste on the flesh side and pressed down to the artificial skull so that it fits perfectly. The lips should be tucked into the slits previously made around the edges of the mouth. The nostril linings can be pushed into the openings that have been made for them. The areas around the eyes may be modeled through the natural openings in the skin. Push the glass eyes into position and adjust the eyelids. The skin around the mouth and eyes may be held in place with insect pins.

Drying Out Mounted Specimen

When all of the parts have been assembled and the animal has been put on a base, place it in a good warm room, in front of an oscillating electric fan to dry. The constant motion of the fur while the skin is drying separates the hairs and gives a very satisfactory appearance. Never attempt to mount an animal at a season of the year when there is not good drying heat available.

After the specimen has dried out, the different parts that have color in life should be touched up with paint and wax. Put the vibrassa back in position, making a hole in the skin for each. Dip the base of each vibrassa in ambroid and place it securely in the hole that has been made for it.

➤ PIERRE CONNER *shows the Hilsch Tube he built and measured to learn the secret of its apparent contradiction of thermodynamic principles.*

Descriptions of Exhibits and Projects That Produced Them By Those Who Did the Work

➤ WHAT OTHERS *have done will often inspire, inform and instruct those who are engaged in doing science projects and building science exhibits to describe what they have done. For this reason, excerpts from many of the reports submitted in the course of the decade of annual national Science Talent Searches for the Westinghouse Science Scholarships are printed on the following pages.*

Obviously no one will wish to copy slavishly what these young people did as their original projects. The projects described in the words of the young scientists themselves are outstanding and worthy of the recognitions that they have had. But they are not necessarily the best projects that have been submitted in the annual Science Talent Searches.

The most advanced and noteworthy projects and exhibits are not always included in these selections because they are not so useful as examples of the sort of exhibits that can be created for science displays and fairs. Some of the STS reports are too specialized to be effective as examples in connection with the wide participation in science by youth that is developing in America today.

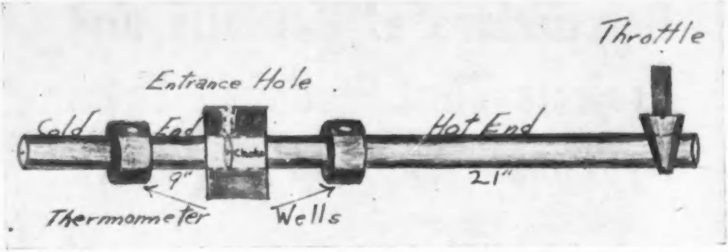
A Hilsch Tube

by PIERRE E. CONNER
Winner Eighth Science Talent Search, 1949.

➤ THERE WAS no published data available on the Hilsch tube at the time I did my experiments. I decided to approach the problem from the thermodynamic angle, and the following are the facts I found.

1. The dimensions shown in the sketch gave the best results, *i.e.*, the greatest difference in temperatures, for the diameter of the pipe and the material used. The entrance hole is one-sixteenth of an inch in diameter, and is drilled tangent to the inner wall of the tube. The hot arm is twenty-one inches long, and the cold arm is nine inches long. The hole in the choke is one-fourth of an inch in diameter. The tube itself has an internal diameter of one-half an inch, and a wall thickness of one-sixteenth of an inch. The arms are of aluminum; the mid-section is brass stock; the throttle on the end of the hot arm is brass; and the fittings are iron pipe and rubber hose.

By attaching the rubber hose to the regulator shown in the picture and then allowing compressed air to enter



the tube, we cause the action to occur; namely, the arms of the tube begin to change in temperature.

In general, the choke hole should be about one-half the internal diameter of the tube for ordinary temperatures. The smaller the entrance hole is, the better.

2. By using a variable pressure attachment (Airco reduction valve) on a small compressor I was able to ascertain the fact that pressure has an influence on the temperatures reached by the arms of the tube.

Furthermore, I found that the temperature at a given pressure would not hold steady for either the hot or the cold end. This is due to the Joule-Thompson inversion that the entering gas undergoes.

3. By experimenting on different days, I found that the temperature of the entering gas affects the temperature reached by the hot arm and by the cold arm.

There is evidence to support the statement that for any given temperature of the entering gas, the hot arm will reach a maximum and the cold arm will reach a minimum which cannot be surpassed nor decreased no matter how much the pressure is increased. It is almost impossible to establish this fact definitely due to the inversion temperature of the expanding gas, however.

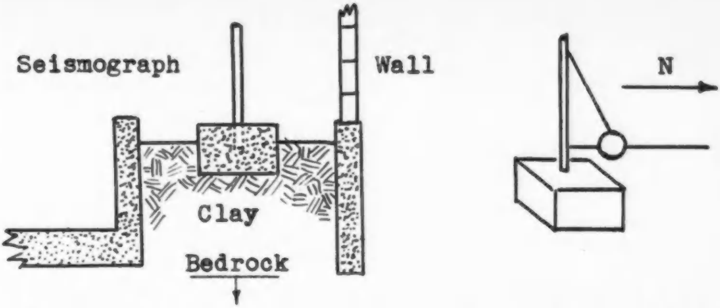
4. I measured the temperature of the hot arm by inserting a mercury thermometer into a thermometer well filled with water. The thermometric method used for the cold arm was simply inserting the thermometer down into the cold arm. I found that the coldest spot of the cold arm is about one inch to the left of the choke and close to the wall of the tube.

A Seismograph

by Michael Lubin

Winner Seventh Science Talent Search, 1948.

➤ Inasmuch as the greater of the two maxima of frequency of earthquakes occurs in January and the smaller in in June, my seismograph, which was completed in August has met with fair success. Even though it is not within two thousand miles of a seismic belt which lies in its cone of sensitivity, it has recorded a few small tremors and one large one (Fair-



banks, Alaska, Oct. 15, 1947).

The seismometer was placed in the cellar with the plane of its upright and arm pointing in a general north-south direction. The reason for this is explained later.

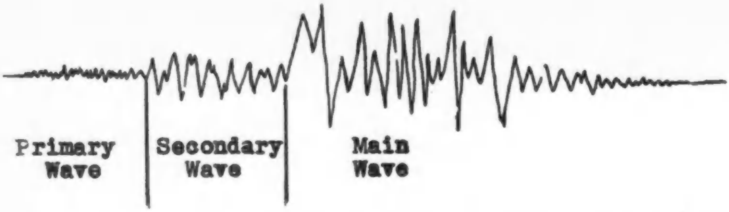
The chief deterrent to the sensitivity of the instrument is the inaccessibility of bedrock, which in this region is more than fifty feet beneath the surface. The clay is which the seismograph is set is only a fair conductor compared with bedrock.

The seismometer is a simple modification of the Bosch-Omori horizontal displacement type, and consists of an upright imbedded in concrete, which is set into the earth. From the upright is suspended a heavy pendulum, and to the pendulum is attached a long extension arm which carries the needle to mark the recording drum. When the earthquake occurs, the tremors traveling through the earth move the upright. Because of its great inertia the pendulum remains at rest. The motion of the upright is magnified by the long extension arm.

An earthquake shock consists of three different distinct tremors: the primary wave, which moves the earth particles in the direction of propagation; the secondary which moves the earth particles at right angles to the direction of propagation; and the main wave which acts like the primary. The main wave is the most destructive of the three because of its greater intensity.

All the tremors emanate from the epicenter of the quake simultaneously, but as shown by the seismogram, they do not arrive at the point of recording in the same time order. The primary and secondary waves arrive first because they travel through the earth (the primary is faster), while the main wave travels along the surface and therefore must travel a greater distance. (The fact that the smaller distance traversed cannot alone account for the great precedence of the primary and secondary waves has led to the geological assumption that the earth is more elastic beneath its crust.)

Since the farther away the quake, the greater the difference in length of path of main and primary waves and therefore greater length (in time) of primary waves, the distance of the epicenter of the earthquake from the seisomometer can be computed. From

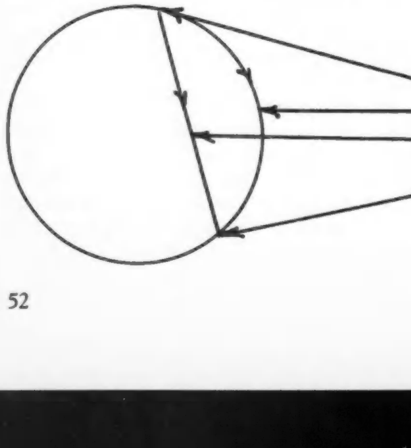


a number of considerations on accurate instruments the formula for distance has been found to be approximately:—

D = 1000 (T-1) where D equals the distance in Kilometers, and T equals length of primary wave in minutes (and fractions of minutes). However, if this formula were applied to the seismogram I made of the Fairbanks quake, the quake would be found to be only two thousand miles distant. Fairbanks is about 3300 miles from my seismograph. This discrepancy is explained by the fact that compared to its Bosch-Omori prototype it is rather insensitive and does not record the beginning of the tremor. As yet I have not received sufficient recordings to formulate an equation which is accurate enough to be worth while.

The exact location of the epicenter of a quake may be found by having three recording stations draw circles on a map with radii equal to the computed distance of the tremor from them and with stations themselves as centers. The epicenter is located at the intersection of the three circles.

The range of my seismometer is at least 3300 miles, since it recorded the Fairbanks tremors. It is most likely much more for a quake occurring on a line perpendicular to the plane of the upright and arm of the instrument. Since the instrument is set up with its plane pointing North-South it will only record shocks occurring in a more or less East-West direction (see diagram). This is understandable since a shock coming from the South would not move the upright in such a way as to make the arm oscillate. The seismograph was erected thus because most of the major seismic belts are west of it.



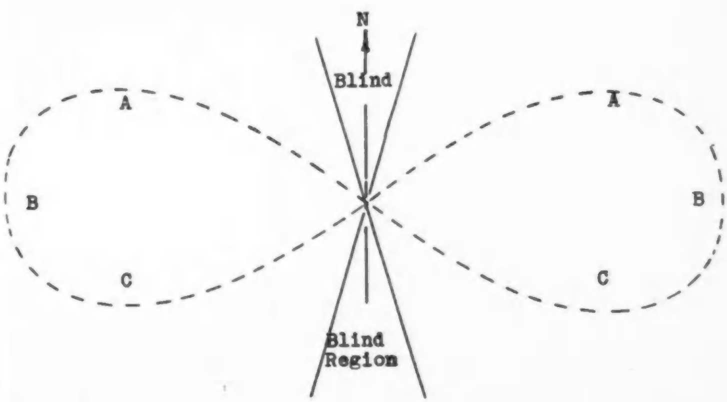
Rossi-Forel Intensity Scale

I	Microseismic	Recorded, perhaps felt by experienced observers.
II	Extremely Feeble	Felt by a few people at rest.
III	Very Feeble	Felt by many people at rest.
IV	Feeble	Felt by people in motion.
V	Moderate	Felt by everyone; furniture disturbed.
VI	Fairly Strong	Sleepers awakened.
VII	Strong	General panic; movable objects overthrown.
VIII	Very Strong	Cracks in walls; chimneys fall.
IX	Extremely Strong	Partial destruction.
X	Disastrous	Complete ruin.

In the diagram the line ABC represents the various positions an earthquake of unvarying intensity might occupy and still give the same recording (as far as intensity is concerned) on the seismometer.

Although the Peru quakes of late October were more intense they occurred due south of New York City and therefore gave only a small recording in comparison with the Fairbanks quake of October 15th. The seismogram of that tremor showed all phases and once the distance was known (from the radio) the intensity was estimated from the seismogram as approximately VI on the Rossi-Forel scale.

My estimate turned out to be rather accurate: later the papers said it was strong enough to break windows at Fairbanks.



➤ ALAN JOHNSTON *demonstrates the arc-forming part of his spectrograph.*

How I Made a Spectrograph

by ALAN JOHNSTON

Winner Seventh Science Talent Search, 1948.

► IN CONSTRUCTION of a spectrograph at home, with minimum facilities, the simplest types possess the most appeal. For this reason the Barlow type is attractive because it uses the same lens as a collimator and as a camera lens.

The lens is one which I ground and polished. It has only one element, as spherical aberration can be corrected with a simple lens, and chromatic aberration causes no image defect in monochromatic light in the spectrograph. My lens has a focal length of 21 inches, giving a dispersion of about 3.2 inches from 4000 Å to 8000 Å.

Two prisms of the equilateral form with 1-inch faces were provided as a dispersing medium. They transmit enough light to give satisfactory exposures in less than five seconds, using an arc as the light source. Two flats are required, which were made of selected pieces of ¼-inch plate glass, silvered on the front.

In order to secure the spectrum of an element, some form of it must be vaporized. The carbon arc presents the most practical means for accomplishing this, since it is able to give the spectra of at least 70 of the elements. An arc was constructed as a light source for the spectrograph. It operates from the usual house current, 110 volts a.c., drawing from five to seven amperes.

The current-carrying carbons are fed by a screw fitting which also serves as the electrical connection. The sample is held either in a small cup in a third carbon or in drilled holes in the current-carrying carbons. The addition of volatile salts to the arc serves to stabilize it greatly and allows the carbons to be drawn farther apart. This is an advantage, since it is the light given off by the gases between the carbons which is wanted in the spectrograph.

In the most usual application of the spectrograph, that of qualitative analysis, the bright line spectrum, as emitted by the arc, is used. The value of the spectrograph is due to the fact that the bright lines in the spectrum are fixed in position, and each line is associated with some one element. In order to determine which element has produced a line, the position of the line in the spectrum must be accurately known.

Since many lines or configurations of lines, whose wavelengths are known, are easily recognized, the relative position of an unknown line can be determined by measurement. A formula has been developed by Hartmann which will give the wavelength of the unknown line from one measurement if its two constants, which apply only to one setting of the spectrograph and to one reference line, are determined beforehand by measurements taken from three known lines. Although an approximation, the formula fits the curve of prismatic dispersion quite well. The general formula is:

$$W = W_0 - \frac{bD}{D + a}$$

Where W = the wavelength to be determined

W_0 = the wavelength of the reference line

D = the distance from the reference line to the unknown line

a and b are constants.

The constants a and b must first be determined from three lines whose positions are known. When the wavelengths and positions of three lines are given, the solution of the formula for the constants could proceed as follows:

$$\text{Let } W - W_0 = y$$

y and D will be known, so:

$$y = -\frac{bD}{D + a}$$

$$y(D + a) = -bD$$

$$yD + ya = -bD$$

$$ya = -bD - yD$$

$$\text{(a)} \quad b + \frac{y}{D}a = -y$$

With data from three lines:

Ca 3933	D = .000
Ca 4226	D = .675
Ca 4455	D = 1.080

Using Ca 4455 as the reference line, two simultaneous equations are set up from: $y = -229$ $\quad D = -.405$

$y = -552$ $\quad D = -1.080$

From equation (a)

$$\begin{aligned} b + .565a &= 229 \\ b + .483a &= 522 \\ \hline .082a &= -293 \end{aligned}$$

$$a = -3575$$
$$b = 2249$$

Substituted in the original formula, these values for a and b give

$$W = 4455 - \frac{2249D}{D - 3575}$$

when D is expressed in thousandths of an inch.

The formula obtained in this manner gives a very satisfactory fit with other known lines and can be assumed to be accurate with the unknown lines.

Separate from this accurate work on photographs is the field of absorption spectrometry, as applied to light transmitted by liquids and solids. For this the light source is an incandescent lamp, and visual observation becomes simpler and faster than photographic observation.

Through the spectroscope transparent objects are shown to possess their color because they absorb sections of the spectrum and transmit other sections undiminished. Differences in colors which are similar to the eye are easily detected with the spectroscope. Dyes and indicators are an interesting group for study in this manner. Aqueous solutions of various concentrations can be made up and examined in transmitted light with the spectroscope. The characteristics which give them their colors are easily seen. Absorption of either end of the spectrum is common, and absorption of the middle section may be noticed. However, a solution is seldom found which has absorption bands which are at all narrow.

Apart from solutions, the principle of filters is clearly shown. Each type of filter absorbs a certain section of

the spectrum in order to give the desired effect on the photograph.

One of the experiments conducted in this branch of spectrography was a comparison of basic phenolphthalein and potassium permanganate solutions of equal intensity. While indistinguishable by the eye, they are easily separated with the spectroscope. The permanganate has several narrow bands in the green, while the phenolphthalein has the entire green absorbed.

In another experiment the color change of indicators was observed with the spectroscope as their pH was slowly changed. A basic solution of methyl orange has a yellow color, caused by absorption of the violet, as seen in the spectroscope. When the indicator changes color from yellow to orange, as the solution is slowly acidified, the spectroscope shows that an additional section of the spectrum, including the blue and green, has been blocked off.

Infrared Spectroradiometer

by John Demkovich

Winner Tenth Science Talent Search, 1951.

➤ For the past two years, my chief scientific interest has been research in the spectroscopy of the visible region of the electromagnetic spectrum. After several years of working with colored spectra, however, I became determined to learn about the rays which I knew existed on either side of the visible spectrum—the infrared and ultraviolet rays. Because infrared spectroscopy seemed to be the more convenient of the two for me to study, I chose to investigate this science at first hand by actually constructing an infrared spectrometer and then applying and using it as I had done with my spectroscope for the visible portion of the spectrum. This work has proved to be of great interest to me, not only because I enjoy all types of spectroscopy and like to construct optical instruments, but also because I am exceedingly interested in qualitative and quantitative analysis.

My science project, then, is the creation of a spectrometer (utilizing rock-salt optics) which decomposes infrared rays from the object under test into a spectrum. This spectrum, after being charted into wavelengths, enables the spectroscopist to learn a great deal about the nature of the substance under observation.

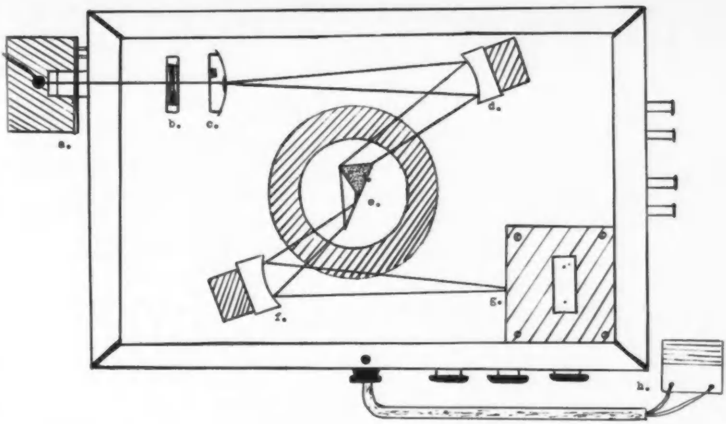
The ideal rock-salt prism for an infrared spectrometer has 60° angles, highly polished, plane faces, and is about 2 x 2 inches in size. The crude pieces of rock-salt which I had to work with contradicted this description; I knew that even the most perfect crystal in the lot would require a great deal of working. I put aside four or five pieces which appeared to be the best specimens, and proceeded to examine their structures and properties (cleavage lines, hardness, brittleness, etc.).

METHOD TO BE USED TO CUT OR GRIND PRISM TO SIZE	WHY SUCCESSFUL (WHOLLY OR IN PART)	WHY UNSUCCESSFUL (WHOLLY OR IN PART)
a. Cutting with a very fine saw.		wholly unsuccessful—causes much jarring and many fissures in the crystal
b. Filing with a flat machine file.	partially successful—makes smooth surface	partially unsuccessful—causes much jarring and chipping
c. Rubbing on dry carborundum polishing stone.	partially successful—very little or no jarring	partially unsuccessful—SiC has poor cutting effect
d. Placing portion to be taken away into water (dissolving)	partially successful—removes unwanted portions quickly	partially unsuccessful—water affects other part of crystal also
e. Rubbing on wet carborundum polishing stone (*Method used*)	wholly successful—abrasive surface and dissolving effect combined	

I found that the cleavage lines of rock-salt crystals run perpendicular to each other; that is, rock-salt grows in crystals shaped like a box or a cube. I also found that the crystal is very brittle and cracks along its cleavage lines when jarred. This meant that I would have to handle them very carefully. Rock-salt also has the property of deliquescence — it tends to melt when the surrounding air is too moist. In order to make a prism out of a piece of this rock-salt, it would be necessary to cut the crystal into a smaller one with three 60° angles; this would be the prism blank. Then I would have to make the faces smooth and flawless. While performing these operations, however, a jar along a cleavage line might cause the crystal to fall apart.

The foremost problem was cutting the prism to size. Here I needed to search the field of crystallography for the methods of cutting and polishing crystals. (Techniques which apply to quartz and diamond crystals could not be used.) I could find no reference to the techniques of cutting salt crystals in any of the literature in the field, so I set out to find a way to cut and polish a salt crystal into a triangular prism with 60 degree angles. In the chart I have summarized the methods I used, and why they were successful or unsuccessful.

After trying some of these methods on usable crystals, I decided that,



➤ ROCK-SALT *prism is the heart of Demkovich's spectroradiometer.*

without a doubt, I would grind the crystal to a 60 degree prism by rubbing the rock-salt on a wet carborundum stone. With this method, I would be dissolving the material away as well as grinding it down. The crystal responded very nicely to this treatment. During this time, I had been keeping the best crystals in a not too dry, or too moist place. I found that a dessiccator had a dehydrating effect on sodium chloride crystals, causing them to become very brittle. Some of the crystals which I had originally put into the dessiccator had become so dry that they crumbled at the slightest jar. After two days of grinding and carefully measuring the angles to be positive that they were 60°, I had my finished prism blank. It is rather small ($\frac{1}{2}$ x 1 inch) but quite serviceable. In order to complete the prism, I had only to polish the faces. I found that the best way to do this is simply to rub the prism on a flat, wet surface. I now had the finished 60 degree prism—the most important part of my infrared spectroradiometer.

A spectroradiometer is designed to measure the intensity of the radiation which is focused line by line upon its detecting device. Even though the rock-salt prism is very important, it is only a small part of the entire instrument. Now that the prism was prepared, I proceeded to construct the other parts. The entire spectroradiometer can be divided into four general parts: the source of radiation, the collimator, the dispersive medium, and the detector.

For the source of radiation, I used a heating element known as the Globar, a rod of carborundum. In order to operate this globar, I attached its poles to an old model train transformer and fitted the rod with a copper-and-rubber-tubing water-cooling de-

vice. When the current is turned on, the globar glows with a brilliant orange light—an excellent light source for my instrument.

The collimator of my spectroradiometer serves to make parallel the infrared rays from the entrance slit, and prepares them to go through the rock-salt prism. The collimator consists of an absorption cell which contains a film of the substance which is being analyzed, then a narrow entrance slit through which the radiation travels, and finally a concave, silvered, collimating mirror. The absorption cell is constructed of two small slabs of rock-salt (which I obtained from the same source as the prism crystal) enclosed in a frame. A tiny amount of the substance to be analyzed is placed between these rock-salt sheets. No glass is used in any instance in an infrared spectroradiometer — all optical parts are either rock-salt, or concave, first-surface mirrors. The homemade slit is unilateral and is mechanically operated by a knob on the front of the panel. The collimating mirror is a small watch glass with a layer of aluminum glazing applied to the front surface.

From the collimator, the rays travel into the rock-salt prism which is the dispersive agent of the spectroradiometer. After leaving the prism, the rays strike another concave, aluminized mirror, and are thrown directly into the thermopile, an instrument which determines very slight temperature changes. I designed my thermopile after the suggestions in Strong's "Procedures in Experimental Physics." The thermopile is connected to a sensitive galvanometer; these two devices together form the detector of the instrument. The purpose of the detector is to make the invisible infrared rays visible in the form of deflections on the galvanometer. From an inspection of the readings on the galvanometer as the prism is rotated on its axis, the different regions of the infrared spectrum will fall upon the thermopile in order, and a complete reading of the infrared spectrum of the substances can be made.

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Low Cost Materials

by RICHARD HAYES

Winner Sixth Science Talent Search, 1947.

➤ MY SPECTROGRAPH consists of an electric arc made from a ringstand, laboratory clamps and an old toaster; an adjustable slit made from a razor blade and parts of an Erector set; a collimator and a telescope, made from lenses set in iron pipe; a camera made from wood; and a prism. I have, however, replaced the original home-made slit and collimator with commercial models which were given to me. The total cost of the spectrograph was under four dollars.

Use of the Collimator

by DOROTHY MARGARET KOHNEN

Winner Fifth Science Talent Search, 1946.

➤ I CONSTRUCTED the collimator to change the diverging rays of light to parallel rays. It consisted of a tube with an achromatic lens at one end and a slit at the principal focus of the lens. When the instrument was assembled I tried it with and without the slit. Without it I could see several spectra, one after another. With the slit there was just one spectrum.

The prism I used was a 60° triangle of glass with an index of refraction of about 1.5. Finally I made the telescope with two converging lenses of 10 cm. and 15 cm. focal lengths. Without the telescope the spectrum was rather hazy and difficult to see. I determined the position of the collimator, prism and telescope from the resulting spectrum.

I made a solution of methylene blue. It came in the form of a red powder, because of the light it reflects, but in water it made a blue solution, because of the light it transmits. It seemed tc transmit only blue light, but when viewed through my spectroscope it showed some green and a definite red line. Later I tried some Tintex that showed a pure red. When I mixed the right proportions of the Tintex and methylene blue solutions, no light would penetrate the liquid, since the red dye transmits only red light and the other only blue. I discovered that some black ink designed for V-mail was surprisingly red. I learned that it is used because red photographs black.

Additional Refinements

by EVA NOVOTNY

Winner Tenth Science Talent Search, 1951.

➤ THE BODY of my spectroscope was constructed from plywood. Its greatest length is twenty-one and a half inches. There is an opening at one end for the diffraction grating. At the opposite end is a slit which can be adjusted by turning a projecting rod to which a sliding door has been attached. The slit is formed between the sliding door and a stationary panel.

Scintillation Counter

by Robert Detenbeck
Winner Ninth Science Talent Search, 1950.

After building a Geiger-Mueller counter, for the chemistry class to use to study radioactivity, this student went to study the scintillation counter, based on the flashes of light that can be seen when a radioactive source is brought near a phosphorescent material.

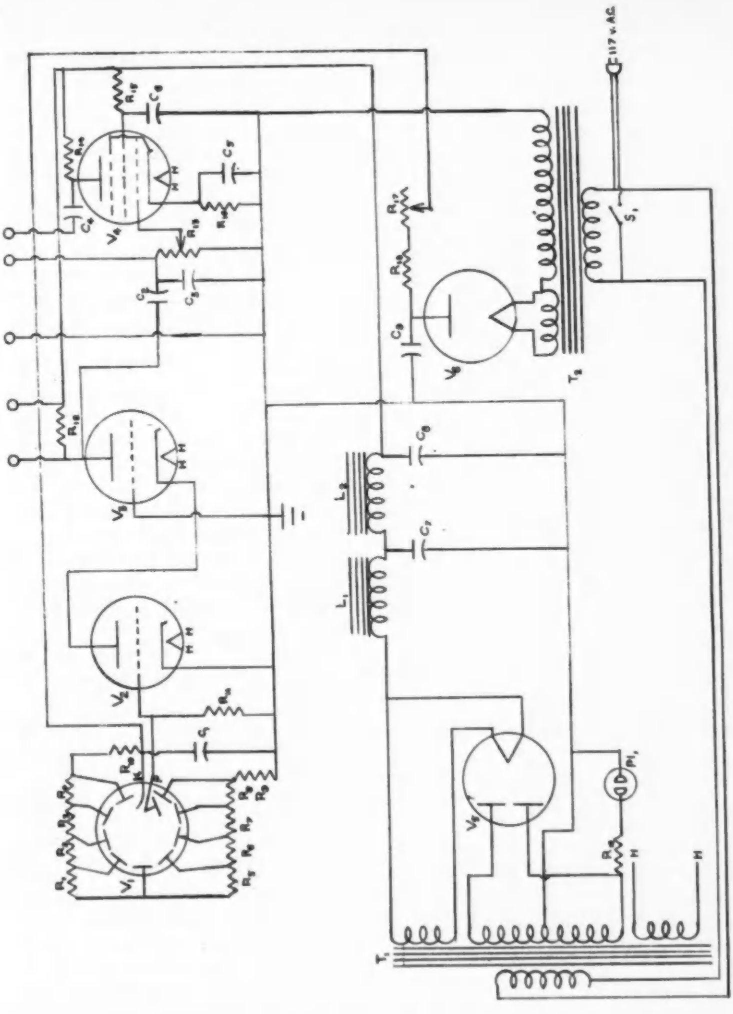
➤ The important parts of the photomultiplier, as it is called, are the electron-multiplier surfaces. These are coated with caesium antimony ($SbCs_3$). When struck by an electron emitted by the photocathode, the first surface emits several secondary electrons. The secondary electrons are drawn by a positive potential of about 100 volts to the next surface, or dynode, where the current is again multiplied several times. This process is continued as the electrons make their tour of the other dynodes. The gain due to electron-multiplication in the 931-A photomultiplier is about 10^6. Since the photomultiplier response time is about 10^{-8}, the phosphor determines the recovery time.

By using appropriate phosphors the scintillation counter can record a-rays, β-rays, γ-rays, high-speed ions, neutrons, X-rays, and mesons. So far I have used silver-activated zinc sulfide and naphthalene as phosphors.

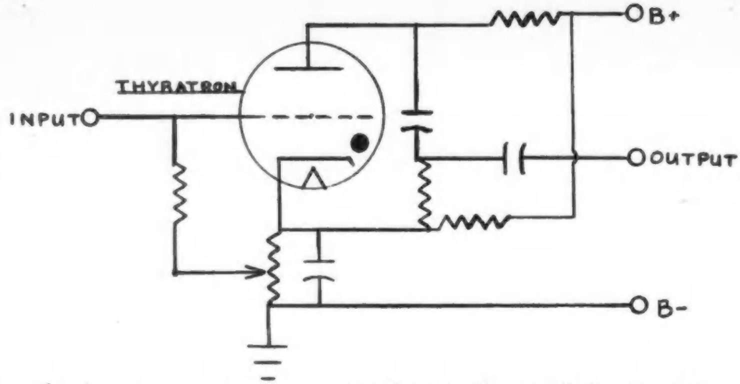
The zinc sulfide phosphor is a Patterson-D fluoroscopic screen made by E. I. duPont de Nemours and Company. It responds to a, β, γ, and X-rays. Since I have not yet used it with an optical system to focus more light on the photocathode, only a-ray and β-ray scintillations are bright enough to override the noise level of the 931-A. X-rays are easily detected and measured by a scintillation detector using this type of phosphor, but the high intensities often involved lead to fatigue of the multiplier surfaces of the photomultiplier and consequent inaccuracies. By impregnating the zinc-sulfide phosphor with a boron compound, neutrons can also be detected.

For detection of β and γ-rays I use naphthalene crystals. Clusters of small crystals have been used in lieu of one larger crystal because of the time involved in successfully growing large crystals. Next year I should like to try growing a large one, however, and compare the results. Dr. H. Kallman of the Kaiser Wilhelm Institute for Physical Chemistry has obtained γ-ray efficiencies of 20 per cent by using naphthalene blocks ½-inch thick over the sensitive portion of the photomultiplier. I have found also that it gives a considerable increase in light output over silver-activated zinc sulfide. The reason for the high efficiency of a naphthalene phosphor is that the substance is transparent to its own fluorescence.

One of the limitations of the secondary electron-multiplier scintillation counter is the noise of the dark current caused by thermal emission from the photocathode. Some of its annoying effects can be eliminated by a thyratron discriminator, which I intend to add to my counter as soon as pos-



➤ WIRING DIAGRAM *of Robert Detenbeck's Scintillation Counter.*



▸ NOISE REDUCER *incorporated into Detenbeck's Scintillation Counter.*

PARTS VALUES

C- 1	2 mfd. @ 1200 v. paper
C- 2	.0068 mfd. @ 500 v. mica
C- 3	50 mmfd. @ 500 v. mica
C- 4	.1 mfd. @ 600 v. paper
C- 5	.1 mfd. @ 600 v. paper
C- 6	.1 mfd. @ 600 v. paper
C- 7	40 mfd. @ 450 v. electrolytic
C- 8	40 mfd. @ 450 v. electrolytic
C- 9	.5 mfd. @ 2000 v. oil
R- 1	100 K. @ ½ watt
R- 2	100 K. @ ½ watt
R- 3	100 K. @ ½ watt
R- 4	100 K. @ ¼ watt
R- 5	100 K. @ ¼ watt
R- 6	100 K. @ ½ watt
R- 7	100 K. @ ½ watt
R- 8	100 K. @ ½ watt
R- 9	100 K. @ ½ watt
R-10	100 K. @ ½ watt
R-11	1.5 meg. @ ½ watt
R-12	.5 meg. @ ½ watt
R-13	.5 meg. pot.
R-14	5 K. @ 2 watts
R-15	10 K. @ 2 watts
R-16	2.2 K. @ ½ watt
R-17	7 meg. pot.
R-18	100 K. @ ½ watt
R-19	2 meg. @ ½ watt
L- 1	15 hy. @ 60 ma.
L- 2	15 hy. @ 60 ma.
T- 1	Power transformer 5 v. @ 3 A., 6 v. @ 3 A., 600 v.c.t. @ 60 ma., 117 v. 60 cycles primary
T- 2	High voltage transformer 5 v. @ 3 A., 800 v. @ 4 ma.
V- 1	931-A photomultiplier
V- 2	6C5
V- 3	76
V- 4	41
V- 5	80
V- 6	71-A (diode-connected)
S- 1	SPST toggle switch
Pl-1	Ne-51 neon lamp

sible. When the grid bias to the thyratron is properly adjusted, the pulses from the scintillations fire it, but the weaker noise pulses are ignored. However, there is no plateau level for the threshold voltage. When it is set so that a negligible number of noise pulses pass through, some of the weaker scintillation counts are lost; when it is adjusted to pass the weaker desired pulses, spurious noise pulses can also fire the thyratron. It is therefore desirable to reduce noise before the discriminator. Coltman and Marshall suggest the following methods:[1]

1—selection of phototubes for high signal/noise ratio
2—use of an efficient phosphor
3—collection of as much of the light as possible
4—reduction of thermal emission by cooling
5—incorporation of integrating circuits into the amplifier following the photomultiplier.

[1] Coltman, J. W., and F. Marshall. "Photomultiplier Radiation Detector." *Nucleonics*, Nov. 1947, pp. 58-64.

In the counter I designed and built, methods two and five are employed. The integration helps because, while the noise counts are usually single pulses, the particles cause several groups of electrons to leave the cathode at once, resulting in a multiple pulse. Integration makes the peak voltage of the multiple pulses much higher than that of the noise pulses if circuit constants are chosen properly. In the diagram of my project the first integrating circuit is formed by R-11 and the stray capacity of the input circuit of V-2.

This method, however, must not be carried too far because the time of recovery of the amplifiers is affected. Dr. Kallman, working with naphthalene phosphors, placed the naphthalene between two tubes connected in coincidence. I have found that the voltage on the photomultiplier tube should be varied for optimum results with respect to signal/noise ratio and output voltage. In the experimental model described here, this voltage is variable from the front panel by means of R-17. R-17 varies the voltage on the cathode of the 931-A from about 175 to 1100 volts negative.

Over the sensitive area of the photomultiplier is fastened the phosphor screen. The whole tube is covered with two layers of very thin aluminum foil, obtained from an old condenser. One layer might have pinholes that would emit light. The output of the photomultiplier is amplified by the two-stage D.C. amplifier, in the plate circuit of which a meter shunted by a condenser can be connected to measure high radiation intensities. The output of the D.C. amplifier is also fed to an A.C. amplifier which delivers output to headphones or to the thyratron discriminator. The thyratron can actuate an electronic counter followed by an electro-mechanical one to register the scintillations.

The low-voltage power supply for the amplifiers is of the conventional A.C. type with as much filtering of the output as practical. Not having the money to purchase special parts for the high-voltage power supply, I substituted modified standard parts. In the schematic diagram, T-2 is a receiver power transformer connected for half-wave instead of full wave rectification. V-6 is a 71-A power amplifier triode with the grid floating. C-9 is composed of four ½-microfarad, 1000-volt war surplus oil condensers in series-parallel. C-1 is made up of two 600-volt paper filter condensers of about four microfarads each in series. R-17 is a standard seven megohm potentiometer insulated from the chassis with a special mounting bracket I made for the purpose.

The advantages of the secondary electron-multiplier phototube scintillation counter are numerous. The recovery time is limited only by the phosphor and, with naphthalene, can be made 10^{-7} seconds. There is no dead time during or after each pulse. By integrating and measuring the output voltage, even radiation of such an intensity that most of the pulses overlap can be measured. The versatility of the instrument, as compared with a Geiger-Mueller counter, is great Screens can be made quite easily that will respond to different types of radiation. The principal disadvantages of the instrument are the dark current noise and the small screen area.

Electrostatic Generator

by MARGARETTA VANYA HARMON

Winner Eighth Science Talent Search, 1949.

➤I FOUND that of the two types of electrostatic generators, frictional and influential, the latter is the more efficient, so I chose to make a Wimshurst generator.

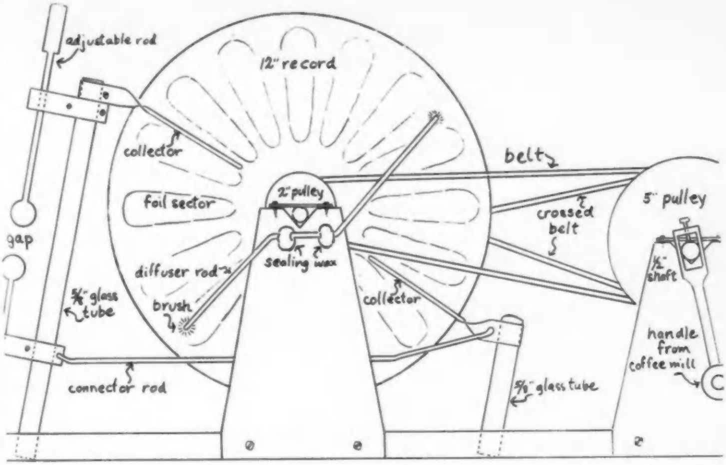
After assembling my materials, I first constructed the wooden framework of the generator as follows: I cut one length of $\frac{3}{4}$-inch by $5\frac{3}{4}$-inch lumber 25 inches long for the base. I made four identical uprights, $7\frac{1}{2}$ inches high and tapered from $5\frac{3}{4}$ inches at the base to $2\frac{1}{2}$ inches at the top. I notched the top edges of 2 of the standards $\frac{5}{8}$ inches deep by 1 inch across the top. This was for the large disk assembly. To accommodate the drive wheels' larger shaft, I cut notches $\frac{5}{8}$ inches deep by $1\frac{1}{4}$ inches across in the remaining two standards. I attached the uprights to the sides of the base with wood screws as indicated in Figure 1. This completed the framework for the generator.

The large disk assembly came next. I first cut the sectors shown in Figure 1 from aluminum foil, 32 in number, each measuring 3 inches in length, 1 inch in width at one end and $\frac{1}{2}$ inch at the other. Sixteen of these I glued to one side of each record, spacing their center-lines $22\frac{1}{2}$ degrees apart.

Next I inserted one piece of steel tubing in each 2-inch pulley so its end was flush with the set-screw flange of the pulley and tightened the screw. I enlarged the center hole in each phonograph record to measure $\frac{1}{2}$ inch in diameter, then slipped a record over the protruding end of the steel tubing. I fastened the record securely to its pulley with sealing wax as indicated in Figure 2.

I next slipped the $\frac{5}{16}$-inch shaft through the two record assemblies, inserting a 2-inch cardboard washer between them. I centered these on the shaft and held them in position fairly close to one another with steel collars as indicated in Figure 2. An additional collar was slipped on each end of the shaft before its ends were placed in the notches on the wooden standards. I slipped a small piece of tin, bent in a V, under each end of the shaft to form a bearing. Then I screwed the short pieces of strap-iron over the notch to hold the shaft in place. These screws make the opening adjustable.

I now assembled the driving mechanism. Over the $\frac{1}{2}$-inch shaft I slipped the 5-inch pulleys. A steel collar was slipped over the ends of the shaft. Then it was fastened in the notches of its wooden uprights, over tin bearings, with the strap-iron pieces as before. The shaft was fastened in position with the collars, allowing one end to project one inch beyond one standard. To this projection I attached the handle with set-screw as in Figure 1. I cut and fitted tightly sewing machine belting between the drive wheels and the pulleys attached to the disks. One of these belts I crossed so that the disks will revolve in opposite direc-



➤ ELECTROSTATIC *generator, Fig. 1.*

MATERIALS I USED

For framework:

- 45 inches pine lumber, 5¾ inches wide, ¾ inch thick
- 8 wood screws, 1¼ inches long

For drive-wheel assembly:

- 2 5-inch, V-grooved pulley wheels, with ½-inch bore
- 1 ½-inch steel shaft, 8½ inches long
- 2 ½-inch steel collars with set-screws
- 2 strips ½-inch strap iron, each 2 inches long
- 2 pieces tin for bearings, ½ inch by 1 inch
- 1 handle from coffee grinder
- 2 lengths sewing machine belt

For large disk assembly:

- 2 12-inch disk phonograph records
- aluminum foil sufficient to make 32 sectors, 1 inch by 3 inches each
- 2 2-inch, V-grooved pulley wheels with ½-inch bore
- 2 pieces steel tubing, each 1¼ inches long, ½ inch outside diameter, ⅜-inch bore
- 1 5/16-inch steel shaft, 8 inches long
- 4 5/16-inch steel collars with set screws
- 1 2-inch cardboard washer
- 2 strips ½-inch strap iron, each 2 inches long
- 2 pieces tin for bearings, ½ inch by 1 inch
- sealing wax to attach pulleys to records

For comb-type collectors:

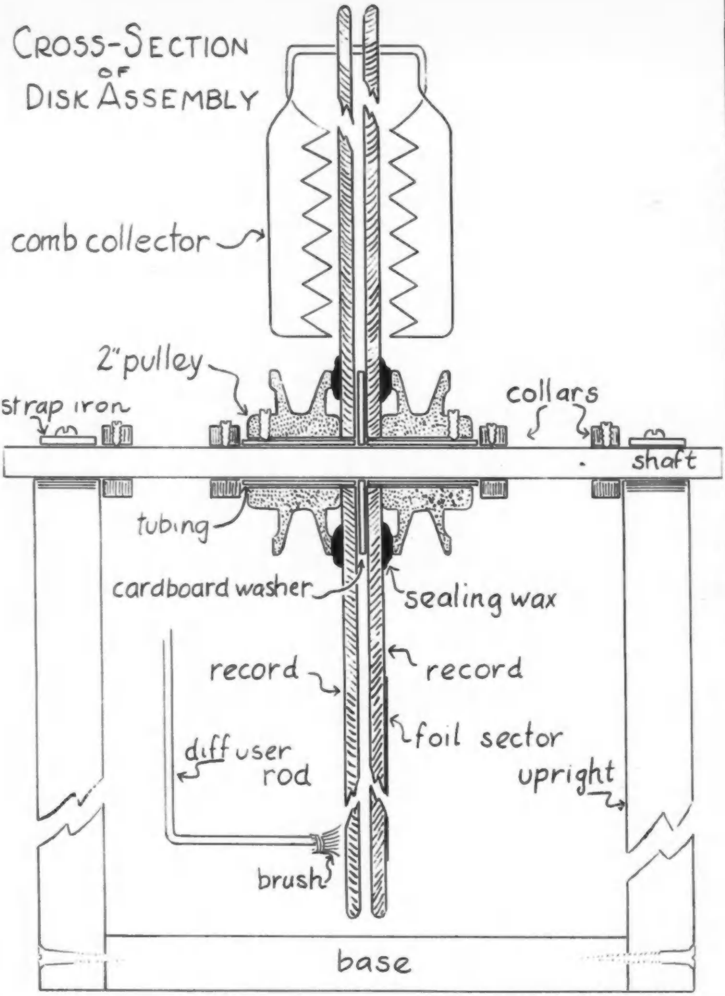
- 28-inch strip of aluminum, ½ inch wide
- 1 piece glass tubing, ⅝ inch in diameter, 4½ inches long

For spark-gap assembly:

- 1 glass rod, ⅝ inches in diameter, 11 inches long
- 12 inches strip aluminum, 1 inch wide, 1/16 inch thick
- 1 iron rod, 28 inches long, ¼ inch in diameter
- 2 ½-inch brass balls
- 1 piece ½-inch dowel for handle

For diffuser rods:

- 2 pieces steel rod, ¼ inch in diameter, each 16 inches long
- 12 inches very fine copper wire for brushes
- sealing wax to attach rods to wooden standards



➤ ELECTROSTATIC *generator, Fig. 2.*

tions. Then I fastened the drive wheels in place on the shaft with the set screws, spacing them in line with the pulleys attached to the disks.

I assembled the spark-gap by bending a 6-inch strip of aluminum around the long glass rod, drilling a hole for a bolt and nut through both thicknesses and bending notches in the free ends to hold the spark-gap rod. I made a similar holder for the other rod to form the gap. I was fortunate enough to secure rods and balls from a piece of discarded electrical equipment to make the gap illustrated in Figure 1. One end of the glass rod I fitted tightly into a hole bored in the base at an 80-degree angle as shown. Over the top end of the rod I slipped the loop of the aluminum comb collector, the ends of which I bent down slightly as shown.

The other collector I fastened to the end of the shorter glass rod which was also inserted in a hole in the base. One end of a connector rod of ⅛-inch galvanized iron wire I fitted into a hole in the side of this collector. The other end I attached similarly to the lower support of the spark gap as illustrated. The gap is easily adjusted by raising or lowering the upper rod. The diffuser rods are likewise ⅛-inch galvanized iron wire, each 16 inches long. I bent each end at a right angle to the shaft, 3 inches from the end. To each end I bound several half-inch lengths of fine copper wire to form a brush. I attached two balls of melted sealing wax to the outside of each standard as illustrated in Figure 1. While the wax was soft, I pressed the center of the diffuser rod in position so the tips of the brushes barely touch the foil sectors on the disks. These diffusers are approximately at right angles on the opposite side of the generator.

I have been able to produce on my generator a continuous spark one inch in length without the use of my homemade Leyden jar. By eliminating more of the leakage, I hope to increase this electrical output considerably.

A photograph of Margaretta and her electric static machine appears on page 14.

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Electricity From Heat

WHEN the junction of two dissimilar metals is heated an electrical current is set up. Although the voltage for each junction is low the amperage may be quite high if the junction is made from rather heavy metals.

While the Science Fair exhibitor can show the electrical values of different metals which produce current when heated, or conversely cool when current is permitted to flow through them, such an exhibit is somewhat too static for popular appeal. It makes a better show if, by a lighting a flame, you can cause a bell to ring.

Make up about 200 pairs of dissimilar wires, cutting the wires to four- or six-inch lengths and twisting two together tightly, such as soft iron wire and electrical resistance wire.

Join the two kinds of wire alternately, to get a continuous circuit.

Portable Geiger-Counter Assembly

by DAVID A. YPHANTIS
Winner Seventh Science Talent Search, 1948.

➤ FOR A LONG time I have been interested in nuclear physics and have felt curious as to the possibility of constructing a small, portable, and yet practical Geiger counter assembly. And so, having some knowledge of basic electronics, I proceeded to design such an instrument. The volume was to be somewhat under two hundred cubic inches, and the weight under ten pounds, batteries included. The voltage output to the Geiger-Muller tube should be variable from seven hundred to fifteen hundred volts. The cost was to be as low as possible and still retain fair quality.

To satisfy the requirements for the power supply of low weight and low current at high voltage (the counter tube in normal operation takes well under 30 microamperes at 1500 volts), a radio frequency fed power supply was decided upon. This supply consists of a radio frequency oscillator, whose output is stepped up to a high voltage and then rectified — an arrangement found in the section on the 1850-A iconoscope in the RCA HB-3 Tube Handbook. This arrangement is, of course, inefficient, and, although the power furnished the counter tube is well under 50 milliwatts, the oscillator should furnish about a watt of power. The tube that seems best to furnish a watt of power from a low voltage plate supply and 1.4 volt filament is the miniature 3A4, which at a plate potential of 150 volts gives 1.2 watts of radio frequency power. For the rectifier either a 1654 or a 1B3/8016 could be used (both being 1.4v rectifiers), but a 1654 is to be preferred because of its lower filament power consumption.

The amplifier section is required to help quench the counter tube and to amplify the pulses from the tube so that they may either be listened to with headphones, or fed to an oscilloscope for visual observation. The first tube in the amplifier is to be biased to cutoff—that is, enough negative voltage is to be applied to its grid so as to render the tube nonconducting—and arranged so as to conduct only when the counter tube conducts. For maximum sensitivity the cutoff voltage should be low and the tube characteristics such that the application of a small positive voltage should make the tube quite conducting, *i.e.*, the tube should be a sharp cutoff tube. The tube that best seems to satisfy these requirements and still be usable in a portable apparatus is the 1S5, a diode-pentode. For the power output, where very little power is needed, a 1S4, triode connected, seemed satisfactory.

To obtain some quench action the anode of the Geiger counter tube is connected to the plate of the 1S5, so that during a pulse, the current from both tubes is added and causes a greater voltage drop in the plate resistor of the 1S5. This helps to lower the voltage on the counter tube and so stop the pulse. Also, during non-conduc-

tion, the plate supply voltage of the 1S5 is added to the voltage supplied by the radio frequency section, which is thus taxed somewhat less.

Most of the quench action, however, is supplied by a ten-megohm resistor between the counter cathode and the negative supply terminal. During a pulse, the counter tube conducts, the current passes through the ten-megohm resistor, a voltage drop appears across the resistor, and the voltage across the counter tube is reduced to the point where the tube no longer conducts. Then the tube is ready for another pulse.

There is a provision for raising and lowering the high voltage so that it may be adjusted to the "plateau" of the particular counter tube used. The voltage change is brought about by changing the oscillation frequency of the 3A4 by means of the trimmer condenser. The more the oscillator is detuned from the resonance frequency of the secondary of the RF transformer, the less voltage appears at the terminals of the secondary.

Construction Details

The voltages of 67.5 for the 1S5 and the 1S4 and 135 for the 3A4 are supplied by two 67.5v portable "B" batteries. The filament power is supplied by two flashlight cells in parallel, while the bias voltages are supplied by a string of six "penlight" cells.

All condensers used are of mica for lesser leakage losses and better general performance. All voltage rating on components, as given in the diagram, are minimum values. The main quench resistor is composed of ten one-megohm resistors in series, as that was deemed the easiest way to provide a high voltage resistor.

The output is brought out through 2500-volt condensers so as to be sure that no high voltage be present in the headphones with respect to the Geiger counter tube. A coaxial connector provides a standard output to any oscilloscope, and two pin jacks provide terminals for connection to the earphones. There is a switch to cut down the amplitude of the pulses. Shielding is provided to reduce radiation.

Properties of Sound Waves

by NICHOLAS REINHARDT
Winner Eighth Science Talent Search, 1949.

➤ MY IMMEDIATE interest is sound waves. I started an investigation of this subject when I noticed that the sound of hammering on a wharf came through the water before the same sound came through the air. The lag increased as the distance between the wharf and me increased. There was also a pronounced echo following the sound impulse arriving under water. Using this echo I was able to determine the velocity of sound in water. I set up apparatus to produce a rapid series of concussions under water at

a point opposite the dam of the pond in which I was doing this experiment. When the frequency of the concussions was such that the returning echo pulses were in zero-beat with the outgoing pulses, an expression could be made of the velocity of sound in terms of the number of impulses per second and the distance from the dam which acted as a reflector. It is $2fs = v$ where f is the number of concussions per second, s is the distance from the reflector, and v is the velocity of sound in the water. The mean of several measurements showed the velocity to be about 4800 ft. per second. In performing this experiment, I had to discriminate against echoes from the sides and bottom of the pond.

I became interested in wave motion and waveform and made a device consisting of a rubber diaphragm stretched over the top of a can with a funnel soldered to the side. When talc dust, paint or sand was sprinkled on the rubber sheet and covered with glass, and one sang lustily into the funnel, beautiful rippled lace-like patterns were produced as the result of the vibrations. Different effects were obtained by substituting black paper of various thicknesses or cellophane for the rubber diaphragm.

I built a carbon telephone transmitter following the diagram of one I had read about but the carbon granules I used would pack. In an attempt to solve this problem I developed a carbon contact microphone which was very sensitive. It was a charcoal stick balanced on a support with one end barely touching a charcoal block. This arrangement was mounted on a wooden cigar box which acted as a diaphragm. It turned out to be extremely sensitive. It could amplify the sound of insects walking on the cigar box and enormously magnify the ticking of a watch. I tried replacing the carbon block with an earphone with a little carbon button cemented to its diaphragm. The earphone was connected to a crystal radio receiver that I had built. Signals were amplified considerably but distortion was so bad that the system really could not be used as a booster to the crystal set.

While trying out the sensitive carbon microphone I began to wonder what made the sound "a" differ from "o" or "e." In reading about sound in connection with the microphone, I had come across an illustration of Koenig's manometric flame patterns, which showed the difference between the waveform of vowels. I decided to make a manometric flame, and going on the explanation given in the text of the physics book, I constructed the apparatus from slats, a funnel, two pieces of glass tubing and a sheet of rubber. For the rotating mirror, I mounted two purse mirrors on a board and put this on an old phonograph turntable. At first I had a lot of trouble with gas leaking through the minute holes which developed in the rubber so I substituted thin paper which was much more sensitive. I soon found that the manometric flame is too insensitive an apparatus with which to see the difference in sounds of a piano and violin, although it is good for differentiating between speech sounds. In order to continue my investigation of waveforms even further, I built a 2″ cathode ray oscilloscope, complete with amplifiers and

sweep circuit, using parts from old radio receivers.

In dealing with complex waveforms I had come across overtones and harmonics which extended up the scale to points completely out of reach of the human ears. I had done experiments with a so-called "silent" dog whistle. It had a frequency of about 20 kilocycles, and I could "feel" but not quite hear its note. Two of them blown together would produce an audible beat note if their frequencies differed slightly. This was my introduction to the field of ultrasonics.

I had previously set up Kundt's dust tube to show standing waves in air. I substituted a short glass rod clamped in the middle for the brass curtain rod clamped one-quarter of its length from each end which I had used before as a source of sound. To set up longitudinal vibrations in the glass rod, I stroked it with slightly rosined silk. By adjusting the tube until standing waves were formed and measuring the distance between concentrations of dust I determined that a glass rod about 8 cm long had a natural frequency of about 30 kilocycles. I had read about magnetostriction generators and piezo-electric transducers but, in attempting to build a more powerful source of ultra-high frequency sound waves, crystal transducers were out because of their great expense, so I tried to make a magnetostriction generator. Attempting to use the magnetostriction or Joule effect I have constructed a feedback oscillator using a 35T transmitting tube from the second buffer stage, and the 1500-volt power supply from the final amplifier of a "ham" transmitter. I wound two coils on the same form, the coils being approximately 25 mh apiece, $\frac{7}{16}$″ inside diameter, $2\frac{3}{8}$″ outside diameter, $\frac{3}{4}$″ wide. One serves as the grid coil, the other as the plate coil. The nickel magnetostriction rod is inside, clamped in the middle by screws coming in from the side between the coils, and is cut 3″ long, which corresponds to a resonant frequency of 33.6 KC. The circuit is capable of handling 100 watts input, and is tunable over a range of frequencies. The sound waves I have produced by this method so far are very weak. Apparently I am driving the nickel rod at one of its harmonics. When I find the trouble and correct it, I intend to drive the nickel rod under oil because the sonic energy transfer would be much greater between the nickel and the oil than the transfer between the nickel rod and the air.

After I build this oil bath, I want to do experiments with the dispersion of metals in water and oil; the formation of emulsions that cannot separate; the formation of alloys of metals that are normally not miscible when molten such as Fe-Pb, Al-Pb, Cu-Pb; the degassing of liquids; and the coagulating effects of ultrasonics on aerosols. I am particularly interested in what occurs when gas bubbles of a certain size vibrate in resonance under an alternating sound pressure because huge stresses and concentrations of energy occur in the liquid which cause reactions which have not been adequately explained.

Graphing by Electronics

by Irwin Cole

Winner Sixth Science Talent Search, 1947.

➤ The idea of graphing mathematical equations on a cathode-ray oscilloscope occurred to me while studying second year algebra. The assembly of the proper controls in a cabinet in conjunction with the oscilloscope made it possible to graph equations very quickly.

Before discussing the method of graphing algebraic equations, it would be helpful to relate my experiences in building the oscilloscope. My original oscilloscope was constructed from a basic circuit diagram from the "Radio Amateur's Handbook," which was essentially a device for lighting the cathode-ray tube and producing a spot on the screen. This diagram had omitted an intensity control which was vital to the operation of the unit, and since the other circuit diagrams were too costly to build, I decided to design this and several other additions myself, using available "junk box" parts.

I discovered that by changing the voltages on the focusing electrodes, the operation of the electron microscope could be duplicated. Unfortunately, specimens could not be placed inside the tube, but a very clear shadow picture of the various elements inside the tube appeared on the screen, magnified several hundred diameters. The image even showed various flaws and irregularities of the metals used in the tube.

After building a linear sweep oscillator, it was necessary to design positioning controls for centering patterns on the screen. This seemed to be quite difficult, as each circuit would cover only one quadrant of the screen. After trying about seven different circuits, one was finally evolved which would cover the entire screen. I now had an instrument which would perform quite well for my purposes.

It was about two months before the need was felt to add any improvements to it. A vertical and a horizontal amplifier increased the sensitivity of the unit to about one volt per inch, making it so sensitive that it had to be rebuilt enclosed in a steel case. Even then, no matter how well the transformers were shielded or the DC supply voltage filtered, there was a slight trace of ripple in the pattern. It was not until another year had gone by, that I learned how to eliminate this fault. I had obtained my radio operator's license from the government, and was discussing the oscilloscope with a friend on the air. He suggested that I obtain a length of two-inch pipe from a plumbing supply company and enclose the cathode-ray tube in it, thus shielding it completely from the magnetic effects of any AC components. This was very effective in eliminating the ripple.

Now the application of the oscilloscope to the graphing of equations may be described. The X and Y axes correspond to the horizontal and vertical movements of the spot on the screen. By varying the voltages applied to the horizontal and vertical

plates, the spot can be made to trace the graph expressed by the equation. Linear and quadratic equations in two unknowns are the easiest to produce, although many others are possible.

Any equation may be expressed by a pair of parametric equations using a third unknown, which in this case is time (θ). In general, if $y = f(x)$, then $y = f'(\theta)$ and $x = f''(\theta)$. When voltage varying as one of the parametric equations is applied to the horizontal deflection plates, and another voltage varying as the second parametric equation is applied to the vertical deflection plates, the image on the screen represents the combined parametric equations, which is the original equation.

To produce the graphs of linear equations, two alternating voltages of the same frequency and of the correct phase relationship are applied to the horizontal and vertical deflection plates. The slope of the line determines the ratio of the two voltages and their phase relationship. If the slope is negative, they will be in phase; if the slope is positive, they will be 180° out of phase. The line may be shifted to the right or left, according to the constant of the equation, by the positioning controls.

The circle is the easiest of the graphs of quadratic equations to produce. It is produced by impressing two full voltages of the same frequency but 90° out of phase, on the horizontal and vertical deflection plates. By changing either the horizontal or vertical voltage, an ellipse is formed. The ellipse may be rotated on the axes by varying the phase relationships of the two voltages. Its location with respect to the origin can be set with the positioning controls.

The general equation for the circle is $x^2 + y^2 = R^2$, which can be broken down to the two parametric equations $x = R \sin \theta$ and $y = R \cos \theta$. When both parametric equations are functions of θ, as is the case with the circle, the frequencies of the voltages are equal. When one equation is a function of θ and the other equation is a function of 2θ, as is the case with the parabola, the frequency of one voltage is twice the frequency of the other voltage. In every case, the magnitude of the voltage is determined by the constant R. Since the only difference between $\sin \theta$ and $\cos \theta$ is that one is 90° out of phase with the other, by having one of the applied voltages lag the other by 90°, all of the mathematical conditions of the parametric equations have been complied with, and the resulting curve is a circle.

The value of this project has been not only to make me familiar with the construction and applications of the oscilloscope, but also to further my knowledge of the graphing of algebraic equations.

Tracing Harmonic Curves

➤ WHEN two interconnected pendulums swing in planes at right angles to each other they produce harmonic curves. These often are shown experimentally by a tiny stream of sand flowing from a funnel, which is one of the pendulums. Blueprint paper can make the record permanent.

➤ NANCY JEAN ROWE *explains her project in microscopy.*

Micromanipulator

by NANCY JEAN ROWE
Winner Seventh Science Talent Search, 1948.

➤ IN THE micromanipulator, a needle with a very fine point is a very important part. This was made by softening a glass tube over a flame, and drawing it out. With a little practice I was able to make microneedles much thinner than human hair. The micropipettes are microneedles connected to a hypodermic syringe by flexible tubing. Thus, dye and chemicals can be injected into the cells.

Next, some sort of mechanism was needed to move this needle very short distances This problem was solved by using a combination of ordinary machine bolts with coarse threads which can be bought in any hardware store. Any bolts of slightly different thread pitch can be used, but, since they were available, I used a combination in which one bolt had twenty threads per inch, and the other had sixteen threads per inch. The bolts were connected by a cylindrical sleeve made by threading half of a metal tube to fit the twenty-thread bolt and the other half to fit the sixteen-thread bolt.

Then three angle brackets two and one-half inches long were fastened together so that the three combined had

the appearance of one flat strip of iron with three perpendicular strips arising from it.

The head of the sixteen-thread bolt was placed over the top screw hole of the first angle bracket and soldered in place. Then the connector and the twenty-thread bolt were attached to it.

A metal rod was pushed through the top screw holes of the other two brackets, and soldered to the head of the twenty-thread bolt. A strip of tin soldered to the head of this bolt and sliding through a slot in the top of the middle bracket prevents it from turning with the connector sleeve.

When the connector is rotated a full turn, it moves one-sixteenth of an inch along the sixteen-thread bolt. At the same time, it moves one-twentieth of an inch in the opposite direction along the twenty-thread bolt. The result of this is that the rod connected to the twenty-thread bolt moves one-sixteenth of an inch minus one-twentieth of an inch, or one-eightieth of an inch per full turn. Of course this movement can be reduced by rotating the connector a fraction of a turn.

The needle is attached to a holder at the end of the rod. For convenience, the part of the micromanipulator just described will be designated part A.

Part A was then placed upon two parallel rods soldered to the base of an old ringstand. This formed a pair of tracks for part A to run on.

Another angle bracket was fastened so that one leg was between the two rods and parallel to them.

A sixteen-thread bolt was soldered to it so that when a connector and a twenty-thread bolt were connected to it, the head of the twenty-thread bolt could be fastened near the center of gravity of part A. Thus, when the connector of these bolts is rotated, part A moves back and forth along the tracks.

A bolt was placed through the base in such a manner that when the bolt is turned, an up and down movement of the needle results.

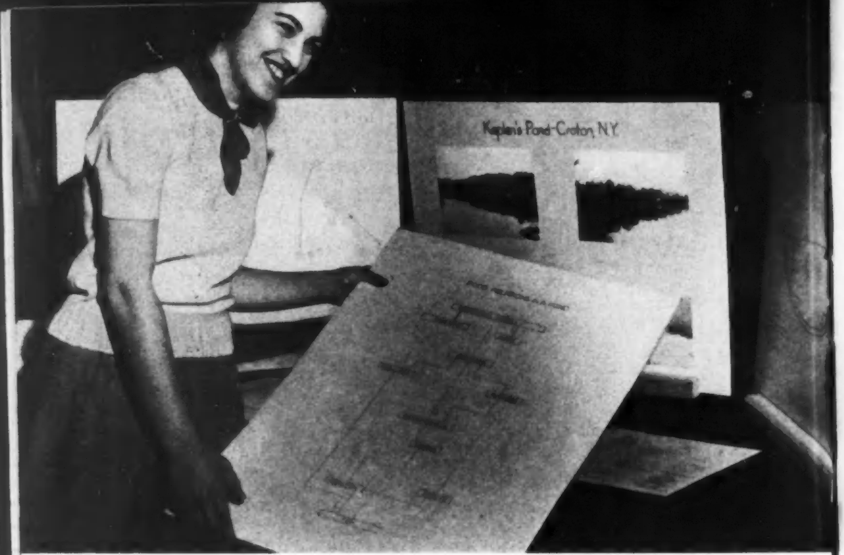
Because such a machine can hold only one needle, two were constructed. One needle is used for holding the cell and the other for dissecting or injecting it.

In operation, if a micropipette is to be used, the syringe, flexible tube, and pipette are filled with the dye or chemical to be injected. The pipette is then clamped in the needle holder of one of the machines. A needle is placed in the other machine.

For low powers, the specimen is placed on a slide with a drop of water over it. No cover glass is used. The microscope is then focused on the cell.

I prefer to keep the needles raised slightly above the slide until they are over the cell to be dissected. They are then lowered by means of the vertical adjustment.

For higher powers, two short strips of metal are fixed on a slide so that the needles may be placed under the cover glass. In this case the specimen is placed on the bottom of the cover glass. Thus, oil immersion objectives can be used. The needle should be slightly curved toward the end so that only its tip will be touching the specimen.



➤ DOROTHY BOTKIN *illustrates her project with charts and photographs.*

Surveys of life forms and living conditions found in certain areas are favorite projects for biology students. The results of such surveys are highly personalized records, being the histories of particular spots, under conditions that prevailed at certain times, observd by individual explorers. The way such hunts were organized, however, how the localities were selected and what life forms were studied, is a record of value to any student planning his own survey. From the following essays has been chosen the description of how each search was organized. Other naturalists will, in a similar way, want to seize upon local areas. These afford the chance to observe organisms thriving in what often seem to be difficult situations.

Ecology of a Pond

by DOROTHY ANN BOTKIN
Winner Tenth Science Talent Search, 1951.

➤ THE SPECIFIC purpose of the project was to identify as many as possible of the micro-organisms of a fresh-water pond. I selected Kaplan's Pond in preference to other ponds in the area for the following reasons: it is a permanent pond, it is near-by, it is not stagnant, and it has not been subjected to chemical treatment.

Kaplan's Pond is located approximately ¾ of a mile east of the Hudson River and 1½ miles north of the Cro-

ton River, in the village of Croton-on-Hudson, New York. The pond has an elevation of 450 feet above sea level, an area of 3.88 acres and a maximum depth estimated at 15 feet. Kaplan's Pond was formed by constructing a stone dam across a brook in 1937. The overflow of the dam forms a tributary of the Hudson River. The pond has a muddy bottom and the water is extremely turbid. Kaplan's Pond is surrounded by flat grassy banks except for a stone wall along the west side and a small sandy beach in the southwest corner.

During the month of October, a sample was collected from the pond in the following manner. A nylon stocking, knotted at one end, was dragged through the water. The solid matter which was deposited in the stocking was placed in a quart jar along with masses of pond scum. The jar was filled with water from the pond.

In the laboratory the contents of the collecting jar was emptied into a large container and three quarts of tap water were added. During the three weeks that this culture was used it was kept in a warm sunny place. The culture was examined with a Bausch & Lomb microscope with magnifying powers of 100x and 440x. To retard the movement of the ciliate Protozoa for identification, a drop of egg albumen was mixed with the specimen.

To obtain as complete and accurate a picture of pond life as possible, I plan to make three more studies of Kaplan's Pond of a similar nature. In this way I hope to identify additional micro-organisms and also to observe the seasonal changes in microscopic life of the pond.

Field Trip Collections

by Owen A. Shteir

Winner Tenth Science Talent Search, 1951.

➤ For my subject of study I chose a small shallow pond which I have attempted to treat as a microcosm in studying the effect of physiographic conditions on animals in winter. Letters A, B, and C refer to regions of the pond which had been dammed forming three distinct areas.

The bottom of the pond consisted of white sand over which muck and decaying organic matter had accumulated in varying depths. I selected what I considered an average area and forced a cylinder 6½ inches into the pond bed. Separating the constituents of the sample by repeated filterings I found it to contain (by weight): 11.38% organic matter, 15.44% inorganic material, 19.51% mud, 53.65% sand.

Because of the pond's extreme shallowness (depth varied from a few inches to about 2¾ feet) light penetrated to every part. Turbidity was affected by even a light rain or wind, owing to the nature of the bottom which was easily disturbed.

I found the water itself was neutral (litmus) and contained few minerals. Soap was very soluble in the water, another indication of its lack of minerals. By evaporating some of the water I discovered traces of white

mineral deposits. The large number of crayfish and snails led me to suspect the presence of some calcium in the water. The water had a slight aromatic odor, indicating the presence of diatoms.

Thermal Conditions—Since thermal conditions are important in determining animal distribution I recorded temperatures at 4 p.m. for 12 days. I found region C to be warmest with an average temperature of 4.46° C. while region A with an average temperature of 3.8° was coldest. I attributed the comparative warmth of C to the numerous springs emptying into it. These springs were usually at 11°, regardless of air temperature, and coled to about 9° by the time they emptied into the pond.

The shallowness of the pond was conducive to sudden temperature changes and an abrupt change in the weather produced an equally rapid change in the water temperature. In general the pond temperature was higher than that of the air, but there was a great deal of variation.

Winter conditions being so severe in a shallow pond, the animal population probably begins to decline with the first frosts and reaches its minimum around February. From the surviving nucleus it builds up slowly in spring and reaches its maximum in midsummer when the pond is swarming with organisms.

During winter most of the animals not hibernating gather in the dense masses of roots or vegetation along shore. I noted certain distinct concentrations of animal life in each region and decided they were due to the type of shelter preferred, the important factors being vegetation, temperature and possibly the type of pond bottom. I have attempted to correlate these concentrations with the conditions mentioned.

As temperature decreases so does the need for food. During occasional warm spells animals would be sufficiently stimulated to search for prey. By keeping several species in an aquarium for a long period I noted their food preferences. Motion seemed to be important in selecting food, for fish were not attracted to still organisms but attacked immediately upon detecting motion.

Land and Fresh Water Mollusks

by Dwight Taylor

Winner Eighth Science Talent Search, 1949.

➤ Nantucket is an island lying off the coast of Massachusetts, thirty miles south of Cape Cod. It is about fifteen miles long by six and a half miles wide. There are some hills, but it is generally low-lying, with many ponds and bogs. A few pine forests exist on it, but on the whole the vegetation consists of scrubby moor plants. Nantucket is composed exclusively of sand with the exception of boulders left by the glacier. Since the line of farthest glacial advance bisects the island in an east-west line, the morainal hills are restricted to the northern half of the island. The southern half is moor land, and contains all the trough ponds.

The purposes of the study were as

➤ Dwight Taylor *shows part of the specimens he collected off Nantucket.*

follows: (1) To correlate the distributions of the various species with the ecologic zones they occupy. (2) To ascertain to what region Nantucket is most nearly related in regard to the mollusks. (3) To determine the extent of the influence of the Gulf Stream on the molluscan fauna. (4) To prepare the way for a comparison of the Recent and Pleistocene shells. (5) To increase the scanty list of mollusks already known from the island.

The area studied comprises the island of Nantucket itself, Tuckernuck Island, the Atlantic Ocean to a depth of fifteen fathoms, and Nantucket Sound to a line between Great Point and Tuckernuck Island. Over the three-summer period, collections were made at approximately one hundred stations in the region. (This does not include the somewhat larger number of localities visited with negative results.) The mollusks thus obtained were identified as far as possible, and listed under an ecologic description of the habitat. By this procedure it was possible to determine the degree of a species' restriction to a given environment.

Collecting in the different habitats was done in a variety of ways to ensure as complete a faunal picture as possible. Among the equipment used were nets, shovels, rakes, screens of various mesh-sizes, clammer's tongs, and dredges. I did not find all the species previously reported from Nantucket, but the methods used probably gave a fair sample of the populations existing when I collected. Since some flux was observed over the three-year period, it seems possible that the forms I did not find are not now present in as large numbers as they have been.

Fishes Off Coney Island

by Malcolm S. Gordon

Winner Ninth Science Talent Search, 1950.

➤ During the period from June 25th to Sept. 9, 1948, I conducted a survey of the shallow-water fishes that abound around the 32nd Street jetty at Coney Island, N.Y., by means of almost daily comparable seine hauls. The purpose of this survey was to determine the relative abundance, seasonal occurrence, and growth of the small fishes present in the water surrounding the jetty during this period.

The results of this survey are given added significance when they are correlated with those of the New York Zoological Society's continuous eighteen year survey of nearby Sandy Hook Bay, though there are major differences between the two. The Zoological Society's work extended not only over a much longer period of time, but it was also not confined to shallow water, consequently they encountered a larger number of species. The present work is the first such done in the area since the Society ceased operations in 1938.

Though the two localities are very near each other, their exposures to the ocean are vastly different. The comparatively sheltered waters of Sandy Hook Bay may be compared to a trap for Southern species that come up along the Coast. On the other hand, the more exposed Coney Island locality is wide open to the pelagic young of various species, creating differences in species occurrence.

Coney Island was originally the westernmost extension of the barrier beaches along the South Shore of Long Island, though it has since been greatly changed. About 1920, great amounts of sand were brought in and dumped to make a larger bathing beach, and small rock jetties about 100 yards in length were built at intervals of about 250 yards to prevent this sand washing away. The jetties, of chunks of rock, have since become thickly grown with rockweed, ulva, etc., and form hiding places for many fish.

The 32nd Street jetty is one of these small breakwaters and divided the area under study in half. I chose this situation because it enabled me to sample the amazingly different fish, both from point of numbers and species occurrence, that showed up on one side or the other according to the state of the tide. The rise and fall of the tide was never any more than some seven feet and never less than five. The bottom sloped gradually so that at dead low tide, at a distance of twenty or so feet from the jetty, around which a sand bank has built up, the water was about four feet deep at a distance of twenty yards from shore. This slope continues for about a quarter mile to a deep ship channel that parallels the shore.

All fish were taken in a small minnow seine, 4′ x 12′, of the type that can be purchased in any fishing tackle store. Collections were made principally as early in the morning as it was possible for me to obtain aid from a friend, as later in the day large numbers of people came to bathe. In general, hauls were made parallel to the

shore, except when the catch was being brought to the beach at the close of the seining operation, and within fifty yards of either side of the jetty. At no time was the water any more than three and one-half or four feet deep.

Notes on the time, weather, wind direction, tide, approximate water temperature and condition were made at the time of operation. I was unable to determine salinity, which varies considerably due to the nearness of the mouth of the Hudson River.

The fish were preserved in 10% formalin in the field. The first specimen of each species was preserved and specimens were taken at ten-day intervals thereafter. Measurements of the living fish were made by means of a measuring board that I made, that was divided into quarter inches. All the fish not kept for preservation were returned to the water.

Ecological Survey in St. Louis

by Jules Alfred Kernen
Winner Fifth Science Talent Search, 1946.

➤ During the summer of 1945 I conducted an ecological survey of a small open area located in the midst of the urban center of St. Louis, Missouri. The primary object of this study was an attempt to ascertain the extent to which the principles of bio-ecology could be demonstrated from an investigation of any limited geographical area which included a sufficiently diversified number of biocenoses. I had become extremely interested in this field of ecological observation for two important reasons: first, a pronounced lack of research was manifested when a study was conducted of previous work in this field, and, secondly, any project of this nature would necessarily result in the acquisition of a large amount of interesting and valuable information relating to the biology of the area—the chief elements of its flora and fauna and the general story of the life-histories of all organisms found within it.

The area which I selected appeared particularly valuable for an ecological study. It was located in a section of the country where rainfall is plentiful, the mean annual precipitation being 36.7 inches, and where the temperature varied, in 1943, from a mean of 56.3° F. to extremes of 101° and −5°. Within its three acres was found and studied an interesting diversification of environmental conditions: the clay of a gently-rolling, dry prairie, the damp bogs bordering a small pond and creek, and the aqueous environment of the pond itself. Finally, the entire area was sufficiently isolated by the surrounding urban areas so that it could be studied as one ecological community, with a modicum of external, biological interference.

The first stage of this survey was a classification of all types of living organisms that could be found within the area. I was able to find two hundred and forty-five species and varieties of plans and animals between June 15 and August 15; specimens of most of these I have mounted and preserved for permanent reference.

Ornithological Study of a Pond

by Garrett C. Clough
Winner Eighth Science Talent Search, 1949.

➤ The lives and habits of birds have always been fascinating to me. It wasn't until three years ago, however, when our family moved near a small pond, that I began to study birds with any scientific curiosity. I noticed the unusual abundance of bird life surrounding the water. Since that time I have recorded my observations of those birds.

My study area, centering around the pond, covers about six acres. More than two acres are shallow water and its shores; about one acre is covered with low brushland and a few large trees, while the remaining land consists of the yards and gardens of two houses. The pond is fed by a running brook from a large lake a mile away. Most of the shoreline is overgrown with tall reeds and weeds to the water's edge. Pickerel weed (***Pondederia cordata***), yellow water-lilies (***Nymphaea advena***) and tussocks of swamp grass grow in the water near the shore. Each year the pond has become more and more filled with water-weed (***Elodea canadensis***) and hornwort (***Ceratophyllum demersum***). The surrounding countryside is made up of pastures, cultivated land, wood lots and overgrown fields.

I have seen sixty-two species of birds on this small bit of ground during the three years. One season thirty-two nests were built here. Compared to the bird census taken in other parts of the country in all kinds of habitats, this is a highly populated area. What importance does the pond have in the attraction of so many birds? Which birds are ecologically fitted to live around a pond and which ones are merely members of the overlapping bird communities? I am able to answer these questions only partially.

Each species of birds has certain requirements for breeding territories. For some birds these requirements are not strict and permit a wide variation, but other birds are closely restricted by them. The supply and type of food is one very important factor that affects bird distribution. The plant growth on the land, which provides food, nesting material, nesting sites and shelter, is another important factor. Others to be considered are terrain of the land, weather, climate, humidity and natural enemies. All the nesting birds which I observed must have found that the pond area satisfied their demands, or else they would not have nested here. By wide and constant observation and by the reading of many books I have come to associate all the local birds with a characteristic habitat.

The species and numbers of the birds which nested on my study area during the last three years are summarized in Table 1. Of these birds, the Red-winged Blackbird is most influenced by the pond. For the rest of the birds, other factors, not controlled by the pond, entered into their choice of a nesting territory. However, they all are somewhat affected by the pond because they live so close to it.

TABLE 1

NUMBERS OF PAIRS OF BIRDS NESTING ON A SIX-ACRE TRACT NEAR NEWBURGH, N. Y., FOR THREE YEARS.

Species	1946	1947	1948
Killdeer	1	0	0
Chimney Swift	2	2	2
Eastern Kingbird	0	0	1
Least Flycatcher	3	1	2
Barn Swallow	0	1	2
Eastern House Wren	0	1	2
Catbird	3	2	2
Eastern Robin	3	3	5
Starling	3	2	1
Eastern Yellow Warbler	2	0	1
English Sparrow	2	1	0
Eastern Red-wing	5	7	5
Baltimore Oriole	1	1	3
Rose-breasted Grosbeak	0	1	1
Eastern Chipping Sparrow	0	1	1
Eastern Song Sparrow	2	2	2
Eastern Phoebe	2	1	1
Eastern Bluebird	0	0	1
Total species	12	14	16
Total pairs	29	26	32

The Red-winged Blackbird is known as a bird of the marshes and lowlands. All their nests here were built of materials gathered from the grass and weeds growing around the pond and were all placed in grass tusocks or suspended among the reeds. The blackbirds ate mostly seeds of the weeds growing thickly around the shores. Some of their food consisted of the various insects and crustaceans which are so plentiful around and in a pond.

The other birds which used things that were supplied by the pond were the Killdeer, Phoebe, Least Flycatcher and Yellow Warbler. Killdeers nested here just once. I believe that was accidental because only one egg was laid and abandoned on the mud of a little island. I have seen Killdeers here every spring and frequently during the summers. These shorebirds came to eat flies, beetles and worms that they find near the edges of the water. I think that Killdeers prefer more open country.

The two flycatchers, the Phoebe and Least Flycatcher, like to nest near water but they also occupy different habitats. Phoebes are found around farms and orchards and along woodland borders. The favorite haunts of Least Flycatchers are old orchards, open woods and parks. Their nests here were placed in the crotches of young trees. The Phoebes made their nests under the eaves of a barn and on the porch of an empty cottage. Mud from the pond was used in the construction of their nests. Aerial insects above the pond furnished part of these two birds' food supply. I have seen them dash out from an exposed perch to capture many insects in midair.

The Yellow Warblers that nested here used materials from pond plants for their nests. Most of the insects which they ate were found on the leaves of bushes and trees and were not associated with the water. Yellow warblers are said to prefer wet or damp areas. All the nests that I have ever seen were in bushy land near water.

The other birds which nested here did so because all their demands were satisfied by the land regardless of the

pond. They could have nested here even if there wasn't a pond or stream near. A few of these birds did use things supplied by the pond but they were things which could have been gotten elsewhere. The Robins used mud from the shores to build their nests but they also used mud from a garden after a rain. The Kingbird which nested here caught many flying insects by rushing out over the pond in flycatcher fashion. Kingbirds as a species, however, are not known to live near water. The Barn Swallows and Chimney Swifts captured many of the insects which were plentiful over the water. I have noticed the swallows touch the water as they skimmed over it. They might have done this to get a drink of water. I have seen Barn Swallows' and Chimney Swifts' nests far from water. The habitats of all these birds are not chosen by the presence or absence of water.

As far as I could see the remaining birds did not receive anything from the pond. English Sparrows and Starlings nested around buildings. Chipping Sparrows, Bluebirds and House Wrens are birds of open, inhabited land. The nesting sites for the latter two were furnished by suitable bird houses. Song Sparrows are widely distributed over all kinds of grassy fields and roadsides. Baltimore Orioles are found only among tall tree tops. Rose-breasted Grosbeaks and Catbirds are birds of woodland borders. These birds belong to surrounding habitats. They cannot be considered as birds of a pond.

During the nesting seasons and summers other birds visited the pond. Table 2 gives the list for the three years. These birds can be divided into two groups just as the nesting birds; those that depend upon the pond and those that came here for other reasons besides the pond. In the first group are the Green Heron, Great Blue Heron, American Egret, Kingfisher, American Bittern, Least Sandpiper, and Pied-billed Grebe. All of these birds ate foods from the pond which are restricted to water. The two herons, the Bittern and Egret stalked along the shore or stood waiting for frogs, fish, tadpoles, crayfish and salamanders. Egrets have come only a few times at the end of the summer of 1948. The Least Sandpiper ate little water insects. A Pied-billed Grebe stayed on the pond for a few days. Grebes depend more upon water than any other bird thus far mentioned. Kingfishers came frequently to catch fish. The home of all these birds was the nearby lake.

The rest of the summer bird visitors did not need anything from the pond. Cowbirds laid eggs in some of the

TABLE 2

Summer visitors to a six-acre tract near Newburgh, N.Y., for three years

- Pied-billed Grebe
- Great Blue Heron
- American Egret
- Eastern Green Heron
- American Bittern
- Least Sandpiper
- Eastern Nighthawk
- Ruby-throated Hummingbird
- Eastern Belted Kingfisher
- Northern Flicker
- Cedar Waxwing
- Black and White Warbler
- Eastern Cowbird
- Eastern Goldfinch

Yellow Warblers' nests but they could have imposed upon sparrows far from water. Goldfinches ate plant seeds from the gardens. A Black and White Warbler passed through here a few times. On some summer evenings I saw Nighthawks flying about high in the air over the pond. Flickers that nested in the woods beyond this area used an old telephone pole as a calling perch. Flocks of Cedar Waxwings came to eat wild cherries from a tree. Ruby-throated Hummingbirds visited the fragrant flowers around the houses. This land wasn't suitable as a nesting territory for these birds. They visited it only when they needed certain things.

As I conclude this summary of my project I can see that whole new ideas of ornithology which I hadn't thought of before are opened to me. I would like to know how birds became suited for a particular habitat in the first place. I wonder what would happen if all of the nesting land of a bird was destroyed. The species might adapt itself to other environments or it might disappear. Would the bird change physically to balance the change in habitat? I wonder how much the removal of one factor which makes up a piece of land would alter the bird life on it. I will continue to observe the birds of the pond and by spring will add about fifteen acres of land bordering the stream to my study area. All I can do now is learn from the observations of others and be constantly on the watch, alert to contribute my partial records for solutions of great unsolved puzzles of nature.

Bird Census

by George Koehler
Winner Seventh Science Talent Search, 1948.

➤I have grown up in a family of "bird-lovers." As far back as I can remember my hobby has been hunting out as many birds as possible so that at the end of each year my list of species would be bigger than that of the previous year. And with this method of study I was content until 1943.

During that year I read J. J. Hickey's book, "A Guide to Bird Watching." This book encourages a more scientific study of birds and suggests many projects which immediately appealed to me. My mother and I decided to go into partnership on a study of the bird life in a given area over a four-year period. During this time we planned to answer several of Mr. Hickey's main questions.

After much consideration we chose the Madison, Wisconsin, Forest Hill Cemetery as our study area. Obtaining permission and a great deal of information from the superintendent of grounds, we made a complete physical survey of the cemetery. We found that the area consists of about eighty acres of gently rolling, rather heavily woded grass plots cut by five miles of winding road.

By January, 1944, we were all ready to start our four years of study. We noticed that most of Mr. Hickey's suggestions could be carried out in one or both of two main fields of research: that of censusing the bird population at regular intervals and that of study-

ing the nests of the birds breeding in the area.

On January 21 we took our first census. Since then we have tried to get in one census a month with weekly trips during the migration periods. A "census" is a count of all the birds in the area at a given time with a complete description of each bird's location, actions, and unusual characteristics. All this data is carefully recorded along with such information as the exact weather conditions under which the trip was made, the time, the route taken over the area, and the weather changes since the previous trip. In addition notes are taken on the changes in singing, feeding, and other habits of the predominant species as the migration periods progress. We have found that with all this information to record our time in the field adds up to only a little more than our time spent on the records.

Of course we very rarely strike the exact number of birds that may be on the area at the time of the census, but we feel that we come very close. We have divided the cemetery into 52 sections, and by a systematic coverage of every section our figures have become very accurate.

During the four years we have seen a total of 106 species in the cemetery, while an additional eleven kinds of birds have been observed flying overhead. Our record for the greatest number of species during one census is forty-nine on May 19, 1944. The greatest number of individuals was observed on June 2, 1946 — 688! The all-time low was set early in 1947 after a two-day blizzard. Two blue jays were the only birds to be found.

The most significant result of these census projects has been the amazing correlation between various weather conditions and the census figures: the effect a heavy snow will have upon the number of ground feeders present; the way a strong wind will drive the small species to the lower, more sheltered parts; the effects of the sun and the time of day on the amount of singing; and the amazing relationship between two graph lines, one representing the temperature on each field trip and the other the number of individuals observed.

The results of these censuses have been many and varied; all have been fascinating. Now, however, I should like to turn to the "nesting" half of our project. I have found the work in this field even more interesting, not only in results but also in the field work itself.

Our aim in this nesting project was to answer for ourselves and for science if possible some of Mr. Hickey's important questions concerning the nesting habits of our most common species. We decided that to do this we must locate every nest in the cemetery for at least four years and keep a complete case history for each one.

Nest hunting, we found, is a most fascinating sport. We learned the many ways of locating a nest and employed them all. Once found, each nest had to be visited three or four times a week so that we might record accurately its progress. And that job was fully as interesting.

Soon we learned that eighty acres of nests to cover meant seven days a week in the field, and just about that much time was required to keep the

	1944	1945	1946	1947	TOTAL
Total number of nests found	166	181	36	63	446
Calculated total of breeding pairs	167	168	*	90	425+
Breeding density (pairs per 100 acres)	190	191	*	112	
Number of species whose nests were found	15	14	5	11	21
Calculated number of species breeding	24	23	*	23	30

* Because of incomplete data, the breeding population for 1946 was never determined.

records up-to-date! We still use the system of recording with which we started: a card for each nest giving the kind of bird, the kind of tree, the height of the nest, a description of the material used, the location in the cemetery, and the day-by-day history of the nest.

We have been very pleased with our results in nesting research. With 446 nests of twenty-one species to observe, we have gathered a great deal of valuable and accurate information. Space will not permit me to go into any detail, but I should like to mention as I did with the census projects the effects the weather has had upon our overall results.

It will be noticed in the chart above that our figures rose in 1945, then were followed by a sharp drop in 1946, with only a minor rise in 1947. This is exactly as we would expect after studying the weather conditions during those four years. The spring of 1944 was perfect for nesting so that a large percentage of the nests were sucessful. The next year an even greater nesting population returned, and, since March and April were abnormally warm, nesting began very early. Tragedy in the form of snow and very low temperature struck in May, however, leaving dozens of baby birds dead in the nest. This accounts for the extremely low population during the next year, 1946. In addition, the spring of 1946 was very cold and wet, discouraging the birds from making more than one attempt at nesting. The 1947 season, which was near normal, saw the birds staging a comeback so that the population next spring may reach the average level.

Many separate projects have been carried on in conjunction with the two main ones, censusing and nesting. I can mention but a few: winter feeding, dawn song censuses, banding of fledglings, egg switching, "parent personality" studies, and special detailed studies of mourning dove and robin nesting.

Of course, the census and nesting phases of my project are not entirely separate from each other. Each aids the other as a check. The censuses are essential in determining the breeding population when all the nests cannot be found.

Additional information on my project may be found in the following publications:

The Passenger Pigeon, Jan., 1945, pp. 15-19. Published by The Wisconsin Society for Ornithology, Inc.

Wisconsin Horticulture, Sept., 1945, p. 23. Published by The Wisconsin State Horticulture Society.

Audubon Magazine Breeding Bird Census, 1944 (pp. 20, 21), 1945 (p. 63), and 1947 (not yet published).

Struggle Among Paramecia

by Leon R. Bush
Winner Fifth Science Talent Search, 1946

➤ As my cultures of protozoa grew, I found that certain types in my mixed cultures thrived, while other types in the same cultures soon died. To determine the cause of this, I decided to experiment. Various factors influence the competition among different species, some of them being light, food, medium, number of organisms in the initial innoculum, and the hydrogen-ion concentration. These factors also have an effect on each other.

For my experiment, I decided to use three types of paramecium, *P. caudatum, P. aurelia,* and *P. bursaria.* These three types can easily be distinguished, and are, therefore, admirably suited for my purpose. The *P. caudatum* are slipper-shaped and about 250 microns long. The *P. aurelia* are also slipper-shaped but much smaller, being only about 100 microns in length. The *P. bursaria* are more rectangular in shape and contain chlorophyll granules, making them appear green in color.

I chose light as the factor which I would vary, since it is very easy to regulate, and I tried to keep the other factors constant. I took five Syracuse dishes and poured 10 cubic centimeters of aged water into each dish. To supply the necessary food I placed half a grain of puffed wheat in each dish. I then carefuly pipetted 10 of each type of paramecium into the first dish and 10 of each into the second. The other three dishes were used as controls, 10 *P. caudatum* in one, 10 *P. aurelia* in the next, and 10 *P. bursaria* in the last dish.

The bottoms of five finger-bowls were lined with moist cotton, and one Syracuse dish was placed in each finger-bowl. The moist cotton assured a minimum of evaporation from the Syracuse dishes. Around the finger-bowl containing one of the mixed cultures I wrapped a strip of black paper and placed a square of the same paper under the cover glass. This prevented light from penetrating.

I had to distinguish among different types of protozoa and count the number of each type. I solved this problem by taking sample drops of my cultures, placing them on slides, and covering them with cover-slips. The pressure of the cover-slips prevented the organisms from moving, and I counted them under a binocular microscope. The success of this method depends upon how accurately the samples resemble the original culture. Therefore I took extreme care to mix the culture well before taking my samples.

I plotted graphs showing the growth of the populations of the three types of paramecium under different conditions. I found that the best type of graph for my purpose is an arithlog graph. This is used to show rates of growth, and parallel lines indicate similar rates of growth. There is a normal curve for the growth of any

protozoa population. This may be divided into seven phases: (1) initial stationary phase, during which there is no increase in population; (2) lag phase, in which the division rate increases to a maximum; (3) logarithmic growth phase, during which the maximal rate is maintained; (4) phase of negative growth acceleration, in which the division rate decreases steadily; (5) stationary phase, in which the population remains constant; (6) phase of accelerated death, in which the total population begins to decrease; and (7) a logarithmic death phase, during which the population decreases at a constant rate.

In my experiment the protozoa used as controls in all three cases thrived better than those in the mixed cultures, showing that the presence of other organisms retards the growth of any one type. In the mixed culture grown in the light, the *P. bursaria* survived the other two types. This is probably due to the presence of chlorophyll in the *P. bursaria*, which helps to utilize the available food and gives it an advantage over the other types. In the culture grown in the dark, however, it was the *P. aurelia* which survived the other two. In this case, the chlorophyll of the *P. bursaria* could not function without sunlight, and the higher growth rate of the *P. aurelia* probably accounts for its survival.

These experiments are not complete, and I plan to do others which involve the other variable factors. But this experiment proved to be a satisfactory beginning in the highly intricate and interrelated series suggested by this one.

Culture Method for Spirogyra

by Anne Wagman

Winner Eighth Science Talent Search, 1949.

➤ Spirogyra is an alga much used in physiological experiments yet most laboratories can not culture it. At Forest Hills High School we have been able to maintain it for eight years in aquarium cultures but there is a need to elaborate a suitable method which can be readily repeated in all laboratories.

Spirogyra belongs to the class Chlorophycae and the order Zygnematales. It is green, has the same pigments as vascular plants, and never grows by means of an apical cell such as is found in the Charophycae, or stonewarts. Its reproductive organs are always one-celled and without a sheath of vegetative cells. Spirogyra reproduces both asexually and sexually. The cells are permanently joined in filaments and each cell undergoes cell division, usually at night. Mitosis occurs first; then the chloroplasts divide longitudinally; finally a phragmoplast, or cell plate, forms between the cells. Sexual reproduction occurs in the fall or under adverse conditions. Two cells from different filaments which are next to each other send out projections. When these meet, the wall between them breaks down and the contents of one cell enters the other.

The active gamete is considered the male gamete and the other, the female gamete. The cell resulting from this conjugation is a zygote. A hard cell wall is then formed and it is now known as a zygospore. This zygospore remains on the bottom of the pond until conditions are more favorable. If conditions are unfavorable and the Spirogyra is unable to conjugate, the protoplasm may contract and the cell will become a heavy-walled resting cell. In my work, therefore, whenever the cell was not completely filled with protoplasm, I concluded that conditions were unfavorable for growth.

I found that the Spirogyra grew best in the tanks containing the most protozoa. Because of this, I decided to try to culture Spirogyra in paramecium cultures. I set up the following general experiment, from the results of which I could expect to get an idea of how to proceed.

I used every combination of distilled water or tap water, hard boiled egg yolk or rice, and paramecia in a ratio of one rice grain or an equivalent amount of egg to ten cc of water. I allowed one week to elapse between the time I put the water, egg or rice, and paramecia into the test tubes and the time I added the Spirogyra in order to allow the paramecia to become established. At the end of another week, the Spirogyra seemed to be forming either zygotes or resting cells. At this point I tried adding more Spirogyra to the odd numbered tubes. Soon after, there was an increase of the alga in all the tubes containing paramecia but the cultures into which I had put additional Spirogyra were only slightly better than those which had received no extra Spirogyra. As a result of my observations, I formed four hypotheses.

1. There is no appreciable difference between those cultures grown in tap water and those grown in distilled water.

2. There is no appreciable difference between those cultures grown with egg as food for the paramecia and those with rice.

3. There is only a slight improvement if additional Spirogyra is added to what appears to be a dying culture.

4. The only condition that made an appreciable difference in the growth of Spirogyra was the presence or absence of paramecia.

In order to continue my search for a favorable culture medium and to test my last hypothesis, I tried more experiments using egg yolk and tap water as my standard medium and adding paramecia to one-half of the jars. Originally I had the jars close to a window, but I found that the light

Testing Growth Conditions for Spirogyra

1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16
Dist. water	Tap water	Dist. water	Tap water	Dist. water	Tap water	Dist. water	Tap water
Egg yolk		Rice		Egg yolk		Rice	
Paramecia				No paramecia			

killed the paramecia. Therefore, I moved the jars into more diffuse light and added more paramecia. These quickly reproduced to form a good concentration of paramecia. Since paramecia were later shown to be essential, I realized that not too strong a light was another necessary condition. After the Spirogyra was added, the paramecia once again seemed to make the difference in whether a culture would live or die. I carried this experiment one step further. I arranged the jars with paramecia in order according to the amount of Spirogyra in each jar. I discovered that this coincided with the number of paramecia in each. That is, the jar with the most Spirogyra had the most paramecia. This relation continued for the duration of the experiment. Each time the amount of Spirogyra in any jar changed in relation to the others, the relation in regard to paramecia also changed. Approximately five weeks after I added them, the paramecia reached the low point in their life cycle and began to die. The Spirogyra also began to die. In an attempt to prevent this, I took some of the Spirogyra from the dying cultures and put it into jars containing fresh paramecium cultures. As yet, I have had no results.

Thus far, my results have all been obtained on a comparative basis. I intend to try to find out whether there is a definite numerical ratio between the concentration of paramecia expressed as the number of paramecia per cc of culture medium and the concentration of Spirogyra expressed as the total length of the filaments. I would also like to try to find the exact substance in the paramecia cultures which provides the favorable conditions for the growth of Spirogyra.

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Erosion Cycle

➤ WATER evaporates from land and sea to form clouds from which rain falls, to meet the needs of plants and animals, then produces streams, rivers, replenishes underground waterways, only to return again to the sea to complete the cycle. The entire cycle, or any of its component parts may form the basis for a simple or elaborate science fair exhibit.

During one part of this cycle ice forms on mountain tops or in cold climates. Where crevices occur in rocks the alternate freezing and thawing breaks the rocks to bits. In more northern climates glaciers develop. These slide ever so slowly, wearing away rock surfaces, grinding the large pieces into fine material. Melting glaciers leave large lakes; or chunks break off in the oceans to form icebergs. Evidences of such glaciation make good photographic and exhibit materials.

Chemical Techniques

➤ CHEMISTRY plays a dual role in exhibit making. It provides materials used in the domains of all the other sciences, and at the same time claims a place for its own techniques as exhibits in their own right.

Many young chemists have brought to the Science Talent Search exhibits of chemicals they have synthesized. In selecting projects for this collection of Exhibit Techniques, however, the editors have chosen the simpler general methods, suitable to the less specialized student's use. The exhibitor who can boast an array of rare chemicals of his own preparation has no problem about his entry for the fair.

Following suggestions from two Science Talent Search winners, one on employing the relatively new methods of chromatography, the other for making the unfamiliar class of compounds in which ammonia takes the place usually occupied by water, there are reprinted here a selection of preparation methods suitable for relatively inexperienced chemistry students. These are from the collection of Burton L. Hawk, whose department "For the Home Lab" is a popular feature of the monthly isues of CHEMISTRY.

Chromatographic Adsorption

by WILLIAM BEAVER
Winner Ninth Science Talent Search, 1950

➤ FORTY-FOUR years ago M. Tswett, a botanist in the city of Warsaw, discovered a unique method for use in separating and analyzing complex mixtures of both organic and inorganic substances.

He placed in the constricted portion of a glass tube a plug of cotton upon which he packed precipitated chalk. He fitted the tube into a vacuum flask and, a moderate suction having been applied, he poured a petroleum ether extract of dried leaves on top of the $CaCO_3$. The column was then washed with fresh solvent.

Under these conditions, the various pigments present in leaves formed separate bands of color on the column, and upon extrusion of the absorbent from the column, were eluted separately.

Using this method, Tswett made extensive investigations of chlorophyll, its derivatives, carotin and associated pigments.

In spite of the obvious value of the Tswett method, it did not immediately find the extensive use it warranted. When, however, in 1931 the carotene of the carrot root was resolved on a column of fibrous alumina into two isomeric hydrocarbons, alpha- and

Adsorbents

listed in order of decreasing activity

Activated alumina (Merck, stand. acc. Brockmann)
Lime (freshly slaked)
Calcium carbonate
Sodium carbonate
Sucrose

Solvents and elutents

listed in order of increasing polarity

Petroleum ether, b.p. 30-65°
Carbon tetrachloride
Carbon disulfide
Ether
Acetone
Benzene 25%, pt. ether 75%
Benzene
Benzene 99%, methanol 1%
Methanol
Water

beta-carotene, researchers from all fields became interested in the chromatographic method. Tswett's discovery was soon utilized in all fields of science for preparing, purifying and analyzing both organic and inorganic substances.

Due to the volatile and flammable nature of the solvents with which I was to work, I located my laboratory in a small room which was walled off from the rest of the cellar by a partition. It had exceptionally good ventillation. The solvents were kept in tight containers, and no flames were allowed in the room.

The adsorption columns I used were made of ordinary lime glass tubing with internal diameters of 4, 6 and 8 mm. They were cut into 12-inch lengths, and plugged with glass wool. When packed into the tube with considerable force, glass wool will remain firm even under a strong vacuum.

The three factors which most affect the success of the method are the choice of adsorbent, solvent and elutent. In my experiments I made use of the accompanying list of adsorbents and solvents, the more polar solvents

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being used as elutents. Some were used in almost all cases, others were utilized only in one or two special instances.

Because there is no established method, but rather an empirical one of selecting adsorbent, solvent and elutent, this selection was prone to be quite costly in both time and chemicals. This was perhaps my biggest problem until I found an article describing a most efficient and simple way of solving it. About a tablespoonful of the adsorbent to be tested is put in a petri dish and shaken to form a wedge-shaped layer on the bottom. A few drops of the petroleum ether extract of the sample are allowed to fall on the edge of the adsorbent from a micro-pipette, followed by solvents in order of increasing polarity. By this method, several tests on different adsorbents and solvents may be carried on simultaneously, without much expense or waste of time.

Reactions in Liquid Ammonia

by Robert Marc Mazo
Winner Seventh Science Talent Search, **1948**

➤ In 1896, H. P. Cady was studying qualitative analysis under Edward Curtis Franklin at the University of Kansas. Seeing that Cady was becoming bored with routine classwork, Professor Franklin gave him some extra work in the preparation and analysis of cobalt ammines. In the course of this work, Cady noticed and remarked to Franklin the resemblance between water of crystallization and ammonia of crystallization in the ammines. This was the start of all the work done in this country on the nitrogen system of compounds.

In order to learn something of this field myself, I was faced with the problem of preparing dry liquid ammonia. To liquefy this gas, dry ice is necessary. To prepare the gas, I tried several methods in which too much heat was needed and too little gas was produced. The final method tried was dropping concentrated ammonia on sodium hydroxide. A satisfactory flow of gas was assured, with little moisture and no heat.

After the method of preparing liquid ammonia had been determined, I tried several reactions using it as a solvent. First, I dissolved alkali metals in liquid ammonia. Sodium, potassium and calcium a'l formed blue-black solutions and crystallized out after the solvent was evaporated, oxidizing very quickly, due to the great activity of these metals.

Then I made some ammines, i.e., inorganic salts with ammonia of crystallization. Many beautiful colors were produced by these compounds. I mixed nickel chloride, cobalt chloride and silver chloride with liquid ammonia. Contrary to the statement of Franklin, the silver chloride did not react. I attribute this to the fact that in its preparation it could not be kept shielded from light. The cobalt chloride ammine gave a pink color and the nickel chloride ammine a blue color.

Home Laboratory Hints

Some of Burton L. Hawk's "For the Home Laboratory" articles are presented because they will be useful to experimenters. The experiments on metals, cotton, boron, laughing gas all contain ideas for exhibits. On p. 105 there begins a series of four articles on the halogens, one of chemistry's better known families famous for its dramatic contrasts and striking similarities. An exhibit built to bring these out, and to show the difference between metals and these typically non-metallic elements could explain many basic facts of chemistry. Illustrations of the manifold uses to which the varying forms of the halogen family are put in many daily applications should furnish a wealth of ideas for exhibit material.

Silver

➤ IT IS POSSIBLE to obtain silver in the pure state from an alloy by chemical means. Place 10 cc. of dilute nitric acid in a flask and add a dime or a quarter, depending on your financial status. Heat the flask gently until the entire coin is dissolved, being careful not to inhale the brown fumes. The solution is colored blue by the copper in the coin, and consists primarily of copper nitrate and silver nitrate. Add an equal quantity of water, mix thoroughly and pour one-half of the mixture in an evaporating dish. Save the other half of the solution for use later on.

If you will refer to the electrochemical series of the metals, you will note that silver is near the bottom of the list. Now the chemistry textbook tells us that any metal in this list will displace a metal that lies below it from solution. The most logical metal for us to use would be copper; if we used any metal above copper, copper itself would be displaced along with silver.

Take a copper coin and clean it thoroughly by rubbing with a dilute solution of acetic acid or vinegar. (This experiment is running into money!) Place the clean coin in the solution in the evaporating dish and let stand for a while.

Mercury is above silver in the electrochemical series and it can also be used to displace silver. This time, use a solution of pure silver nitrate. Add a small globule of mercury and let it stand. Soon you notice crystals of silver "growing" on the mercury.

Electrochemical Series of Common Metals

1. Potassium
2. Sodium
3. Calcium
4. Magnesium
5. Aluminum
6. Zinc
7. Iron
8. Tin
9. Lead
10. Hydrogen
11. Copper
12. Mercury
13. Silver
14. Gold

Now let us go back to our copper coin. By this time sparkling white crystals of silver tinted blue by the solution will have formed. Remove

the coin carefully; wash and dry the crystals. If you wish to obtain a coherent mass of silver, you can do so by melting the crystals. Silver melts at 960°. If you have difficulty in reaching this temperature, we suggest you try using a blowpipe. Place a few crystals in a small shallow container, such as a porcelain crucible lid. Grasp the lid with crucible tongs and point the flame from the blowpipe directly upon the crystals. Then blow, brother blow! Create a steady flame, keeping your cheeks inflated. Finally when your are just about ready to give up, the mass will lose shape and a shimmering white liquid of molten silver will form. Pouring this into a large container of water will produce small white balls of pure silver.

Its Compounds

When the Creator assembled this world of ours from some 92 odd substances, He imparted to the compounds of silver a rather unique property—sensitivity to light. For hundreds of years man used metallic silver, never realizing that the compounds of this metal were as valuable as the metal itself. For upon this seemingly unimportant property the entire photographic industry depends!

You can demonstrate the action of light upon silver compounds in a striking manner. To the second half of the dissolved coin solution prepared earlier, add a solution of sodium chloride. A thick, white precipitate of silver chloride forms. Filter and wash the precipitate thoroughly with water. Next open the filter paper flat and spread the precipitate evenly over it. Lay a hard object, such as a coin, key or nail on the surface of the silver chloride. Now ignite about 2 or 3 inches of magnesium ribbon and hold it directly above the object. After exposure to this brilliant light, the white compound will gradually darken, passing through various shades of pink, red and violet. If the object is now carefully removed, its image will remain as a white design imbedded in violet. Wherever light does not reach, the silver compound remains white.

If sodium hydroxide be added to silver nitrate solution, the brown muddy precipitate of silver oxide is formed. (The hydroxide of silver is not stable.) If this oxide is filtered off and heated, it rapidly decomposes leaving a residue of metallic silver. Silver oxide combined with organic protein preparation forms the well-known antiseptic, *Argyrol.*

The compounds of silver are varied in color. Add a little silver nitrate solution to solutions of potassium iodide (pale yellow); sodium sulfide (black); potassium chromate (brick-red); sodium phosphate (tan); and potassium ferricyanide (orange).

Tungsten

➤ THE REDUCTION of tungsten trioxide, WO_3, is not easily accomplished in the home laboratory. Carbon or hydrogen could be used, but both require extremely high temperatures. Perhaps better results can be obtained by using metallic sodium as the reducing agent.

First, we must obtain the oxide. The most common compound of

tungsten is sodium tungstate and we will use it as our starting point. Dissolve 3 grams of it in 15 cc. of water. Add to this a solution of 5 cc. hydrochloric acid in 5 cc. of water. A white precipitate of tungstic acid forms which rapidly turns yellow. Filter, and transfer the precipitate to an evaporating dish. Heat gently until all water is driven off. Grind the remaining solid to a fine powder in a mortar. Finally, heat again strongly for about 10 to 15 minutes. The powder will turn dark orange but will regain its yellow color on cooling. This is tungsten trioxide, WO_3.

Sodium is a powerful reducing agent and sometimes dangerous; therefore proceed cautiously. Place a *small* quantity of thoroughly dry tungsten trioxide in a thoroughly dry porcelain crucile. Cut a small piece of metallic sodium—*no larger than a pea.* Clean it, cut into several smaller pieces, and drop into the crucible with the tungsten trioxide. Immediately cover the mixture with a layer of common salt, about $\frac{1}{4}$ inch thick. Place a loose fitting cover on the crucible and apply moderate heat. The action should proceed quietly, but it is best to place the apparatus in a place where no danger will occur from flying sparks in the event the sodium becomes a bit obstreperous. Heat for about 15 minutes; then let the crucible cool thoroughly before removing the cover. When cool, carefully shake out the layer of salt. The bottom of the crucible will be covered with a black, brittle powder which, if your experiment was successful, is tungsten. If all the sodium has not reacted it will be necessary to heat again under the layer of salt. Of course you are familiar with the explosive reaction of sodium and water; it will not be necessary to caution you against the careless use of the latter in extracting the metal or washing the crucible. As the tungsten requires a temperature of 3370 degrees to melt it, we will have to be content to leave it in powdered form.

Identification

The "blue oxides of tungsten" present a characteristic test for the presence of that element. Add a little hydrochloric acid to a solution of sodium tungstate and drop in a small piece of zinc. The precipitate formed is first white, then yellow, and finally passes through various shades of blue. The latter color is formed by the reducing action of the hydrogen bubbling through the solution. If potassium ferrocyanide be added to the acid solution instead of the zinc a greenish orange-yellow color is obtained. Stannous chloride gives a white precipitate.

We have found that the easiest way to obtain tungsten is to break an electric light bulb. If you can obtain such a bulb, it will be interesting to verify the composition of the filament. We refer to that portion of coiled, brittle, white wire suspended from wire supports in the center of the bulb.

Our first difficulty is to bring the tungsten into solution. It is scarcely attacked by acids, even by aqua regia. The powdered metal will dissolve in boiling KOH solution, but the solid metal, as in the filament, will not. Our only alternative, then, is fusion with alkali. Place one or two grams of solid sodium hydroxide in an

evaporating dish. Add a small piece of the filament-wire and heat until the solid melts and most of the metal is dissolved. Sodium tungstate is formed. When cool, dissolve in water. Make acid with HCl and add a piece of zinc. The blue color betrays the presence of tungsten.

But suppose you have followed instructions and no blue color is obtained? When you added water to the fused alkali, was a white precipitate formed at first which dissolved when more water was added? If so, in all probability you have a solution of sodium tantalate and your filament was not tungsten, but tantalum.

Boron

➤ EVERYONE is familiar with borax as a cleansing agent and the properties of boric acid as an eyewash are well known. We all have, no doubt, at some time washed our hands with borax and our eyes with boric acid. But despite the popularity of these compounds of boron, the element itself is a rarity.

Boron has very few uses in the elemental state and is extremely difficult to prepare with any degree of purity. Consequently, its production is limited and its price is high. But we feel that it makes an interesting collector's item for the shelves of the home lab and its isolation presents a challenge to the home chemist.

It was in 1808—when Beethoven was composing his greatest music and Napoleon was rising to his greatest power—that boron first appeared as a new element. Its isolation was accomplished by Thenard and Gay-Lussac in France and Davy in England. They decomposed boric acid by heating it with potassium.

This procedure is both dangerous and costly and boron is usually prepared now by reducing the oxide with magnesium: $B_2O_3 + 3Mg \rightarrow 3MgO + 2B$. This method can most easily be employed in the home laboratory.

First it is necessary to prepare the boron trioxide. Place about 5 grams of boric acid in an evaporating dish and heat thoroughly for five minutes in order to drive off the water. Actually, three reactions occur during this heating. The acid first loses a molecule of water to form metaboric acid: $H_3BO_3 \rightarrow HBO_2 + H_2O$. Upon further heating the tetraboric acid (parent acid of borax) is formed: $4HBO_2 \rightarrow H_2B_4O_7 + H_2O$. And finally, the oxide: $H_2B_4O_7 \rightarrow 2B_2O_3 + H_2O$. We are, of course, concerned with the oxide, which is a brittle, semi-transparent, glass-like solid.

Break off a few chunks, and grind in a mortar to as much of a powder as possible. Now take about ½ to 1 gram of oxide and mix it thoroughly with an equal amount—by weight—of magnesium powder. Place the mixture in a crucible, cover it, and heat to redness. It is advisable to continue heating at this temperature for at least fifteen minutes. Then allow the crucible to cool thoroughly; remove the cover, and examine the contents.

The grayish-black mass contains free boron, magnesium oxide, magnesium and a little magnesium boride. Boron is insoluble in hydrochloric acid; therefore it is possible to

dissolve the other products in the acid, leaving the boron as a residue. Scrape the contents from the crucible into a beaker and add dilute hydrochloric acid. Keep adding acid and water from time to time until you are pretty sure that all soluble substances have dissolved. Then filter and dry again. The product is impure boron. It usually is obtained as an amorphous brown powder.

Boron can also be obtained in the crystalline state as grayish-black, hard, lustrous crystals. It is possible to crystallize boron from molten aluminum, although the product contains aluminum boride. You can attempt this crystallization by melting a few pieces of aluminum in a crucible. Sprinkle the amorphous boron in the molten liquid and pour the contents into a large container of water. The aluminum is then dissolved in hydrochloric acid, leaving the boron behind.

It is also possible to obtain boron by heating borax with red phosphorus, the reaction depending upon the strong affinity of phosphorus to oxygen. In all cases the boron is impure. Recently, boron has been obtained in a high state of purity by electrolysis of boron chloride using high-potential alternating current arcs.

Now that you have obtained boron (we hope), the question arises, what can you do with it? Well, the answer is: nothing. As stated previously, boron has very few uses, and pure boron costs about $5.00 per gram. It has been used to some extent in thermometers and thermo-regulators. Because of its extreme hardness, the crystalline form is used in place of the diamond in industry.

So—put your boron in a vial—label it Boron, symbol B, atomic weight 10.82. And take pride in the fact that you have a supply of a "rare" element! And be proud of the fact that you have accomplished the difficult isolation of it in your own laboratory! And rejoice in the fact that you have saved yourself $5.00!

Cotton

➤ More than 20 million Americans depend on cotton for their livelihood, either directly on farms or indirectly from industry. It stands with wheat and corn to form the "Big Three" crops of the United States.

Although grown and used for centuries, cotton really came into its own when the chemist entered the scene. For what he created from cellulose, chief ingredient of cotton, was nothing short of miraculous. No longer used just for fabrics, it now plays a part in the formation of artificial silks, paper, cord, and rope, adhesives, explosives, drugs and medicines, plastics, lacquers, photographic film, phonograph records, and a multitude of allied products. The chemist has succeeded in bringing the raising of cotton to an economically sound basis, literally from "poverty to prosperity." He has even utilized the seed. The all-important cottonseed oil is widely used in lard substitutes, in the manufacture of oleomargarine, as a source of glycerin and explosives, in soaps, lubricants, cosmetics, and cooking and salad oils. And to think that the seed of cotton was once a general nuisance—a "waste product."

Pyroxylin

Absorbent cotton is practically pure cellulose. Let us examine a few compounds of this important substance.

When cellulose is treated with nitric acid several very useful cellulose nitrates are obtained. The "dinitrate" containing 11% of nitrogen is known as *pyroxylin*, or collodion-cotton.

Pour 3 cc. of water into a beaker and carefully add 15 cc. of sulfuric acid and 6 cc. of nitric acid. Cool the solution by placing the beaker in a larger container of cold water. When thoroughly cooled, add several small clumps of absorbent cotton. Allow the cotton to remain in the solution for about 15 or 20 minutes. (Keep the solution cooled all the while.) Then remove the cotton and wash thoroughly with warm water and allow to dry. Do not heat.

Pyroxylin is highly inflammable as can be demonstrated by bringing a small piece to an open flame, using a crucible tongs of course.

Collodion

Pyroxylin will dissolve in a mixture of alcohol and ether to form a syrupy liquid, *collodion*, which is used in cements, lacquers, etc.

Mix together equal proportions of absolute alcohol and ether. Place a small quantity of dry pyroxylin in the mixture. Stopper and let stand for a few days. At the end of this time, pour off a small quantity of the clear liquid into a watch glass. This is, or should be, collodion. Allow it to evaporate at room temperature. A thin film of pyroxylin remains. The film is waterproof, as can be demonstrated by pouring water into the watch glass. Pour off the water, and if you are careful, you will be able to pick up the film in one piece with a pair of tongs.

Celluloid

Celluloid is not easily made successfully in the home lab. Commercially it is formed by blending together pyroxylin, camphor and alcohol. By means of hydraulic presses, the mass is pressed together at high temperatures, cooled somewhat, then molded into the desired shape. Because of its high flammability, celluloid is rapidly being replaced by numerous newer plastics.

Cement

A good "cellulose" cement can be made by dissolving pieces of celluloid in acetone, the thickness of the cement depending upon the concentration of the solution.

Gun-Cotton

The nitrate of cellulose containing 13% or more of nitrogen is known as *gun-cotton*, ("trinitrate").

Carefully mix together 5 cc. of con. sulfuric acid and 6 cc. of con. nitric acid. Cool the solution; then place a small piece of cotton in it for 10 minutes. Remove the cotton and wash thoroughly with warm water. Allow to dry at room temperature. When dry, bring the cotton to a flame. Note the brilliant flash as it burns rapidly. Gun-cotton is used in producing smokeless powders, dynamite, cordite, and other explosives.

Remember, you are working with caustic acids and flammable compounds. Use only small quantities and work carefully.

Cotton: Future

The scientist is a restless creature.

He creates a useful substance. But he is never satisfied. His previous creation is never good enough, and he finds himself forming new and better things today to replace those he produced yesterday.

Rayon is an extremely useful article. But consider nylon. Here is a serious competitor—better, stronger, more versatile—and no doubt it will entirely replace rayon in years to come.

Celluloid, as a plastic, already is a thing of the past. Consider Lucite, Plexiglas, Vinylite, etc.—all up and coming plastics with many advantages over celluloid. Finally, consider soy-bean oil, another competitor of cottonseed oil.

Could the same scientist who brought cotton to the throne contribute to its downfall? For already we are beginning to realize that cotton is no longer king!

Manufacture of Sulfuric Acid

➤ SULFURIC ACID—"King of Chemicals"—is perhaps the most useful compound ever manufactured. It can be used as an acid, catalyst, dehydrating agent, oxidizing agent, electrolyte and solvent. It plays a major role in the manufacture of fertilizers, dyes and drugs, paints and pigments, explosives, textiles, etc. It is used in the refining of petroleum, in pickling of steel, in metallurgical processes, for the manufacture of other important chemicals, in storage batteries, and in many other industries too numerous to mention here.

Sulfuric acid is not easily manufactured. The dioxide of sulfur, SO_2, is a complacent compound and thus is reluctant to accept another atom of oxygen to form the trioxide, SO_3, which is the anhydride of sulfuric acid. To bring about this transformation, the chemist must use rather persuasive methods, such as employing a catalyst. Sulfur dioxide and air are heated and passed over the catalyst, which usually consists of mixtures containing vanadium pentoxide. Sulfur trioxide is formed, $2SO_2 + O_2 \rightarrow 2SO_3$, from which acid is produced.

Another method utilizes the action of the oxides of nitrogen on sulfur dioxide. This is the method which can be demonstrated in the laboratory. Commercially, it is known as the "Lead Chamber" process.

First, secure a flask to be used as the "Lead Chamber," or reaction flask, and fit it with a three-hole rubber stopper. Now we must supply a source of sulfur dioxide. This is most conviently prepared in the laboratory by the action of HCL on sodium bisulfite. Place four grams of the latter in a flask and just cover it with water. Fit the flask with a two-hole stopper, thistle tube and delivery tube. The end of the thistle tube should be just under the surface of the water in the flask. The delivery tube should lead to the reaction flask.

Next we must supply a source of nitrogen dioxide, which can be obtained readily by heating the nitrate of a heavy metal such as copper or lead. Place three grams of copper nitrate in a dry test tube. Clamp in an inclined position and fit with a stop-

per and delivery tube leading to the reaction flask.

An outlet tube is placed in the third hole of the stopper in the reaction flask. This can be connected to a rubber tube leading the offensive gases away, or the gases may be absorbed in water, after first passing through an empty bottle serving as a "trap." This rather elaborate apparatus can be set up in several ways.

Heat the copper nitrate until the reaction flask is filled with brown fumes. Then pour hydrochloric acid through the thistle tube of the SO_2 generator. Allow the two gases to flow into the reaction flask, keeping the NO_2 slightly in excess. After a while, thin white crystals will form in the flask, and will dissolve in any water that may have condensed, forming numerous droplets of sulfuric acid.

After you have choked considerably from the fumes, discontinue the reaction and disconnect the apparatus. Pour a little water on the crystals that have formed. Notice the sizzling sound. Sulfur trioxide reacts with the water to form sulfuric acid: $SO_3 + H_2O \rightarrow H_2SO_4$.

Pour a portion of the acid into a solution of barium chloride. A heavy white precipitate indicates the presence of the sulfate radical. Test the strength of the acid by adding a small piece of zinc; it should react, liberating hydrogen.

Of course this method is not practical, being designed solely for demonstrative purposes. In the commercial Lead Chamber process, the sulfur dioxide is produced by burning sulfur or iron pyrites. The oxides of nitrogen are produced by the catalytic oxidation of ammonia. The two gases, along with air, are led into the Lead Chamber where steam is introduced.

Reaction occurs, producing *nitrosyl* sulfuric acid: $2SO_2 + NO + NO_2 + O_2 + H_2O \rightarrow 2NOHSO_4$, which in turn reacts with more water forming sulfuric acid: $2NOHSO_4 + H_2O \rightarrow 2H_2SO_4 + NO + NO_2$. You will note that the oxides of nitrogen are again produced by the second reaction. These are collected and used over again.

Laughing Gas

➤ BETTER KNOWN as "laughing gas" or "sweet air," nitrous oxide is important as a local anesthetic—it is the "gas" the dentist uses during extraction of teeth. When inhaled it produces somewhat intoxicating effects similar to those produced by an overindulgence in alcoholic beverages—so we have been told.

In order to study the properties of the gas, set up an apparatus whereby you can collect several bottles of it over water—preferably warm water. Use a flask as your generator fitted with a two-hole stopper, thistle tube, and delivery tube. Cover the bottom of the flask with pieces of mossy zinc. Pour 10 ml. of con. nitric acid in 100 ml. of water and transfer the mixture to the flask. If the reaction is too slow, heat until a steady stream of gas is given off and you are able to collect several bottles of it.

One striking property of nitrous oxide is its ability to support combustion. Glowing spinters, steel wool, sul-

fur, etc., burn almost as brightly in nitrous oxide as in oxygen. You can demonstrate this property readily.

Nitrous oxide can also be obtained by heating ammonium nitrate; however, this method is rather dangerous and we do not recommend it. Being of a temperamental nature, ammonium nitrate is not to be trusted. If heated too strongly or unevenly, it may explode violently.

Chlorine

➤ LET US IMAGINE ourselves in the year 1774. And let us enter the laboratory of one Carl Wilhelm Scheele in Sweden. His laboratory is simple; he, of course, has none of the modern equipment which we deem essential in our laboratories of today. He is intensely absorbed in his work. Upon closer examination we find he is experimenting with the mineral *pyrolusite*, which, he believes, contains a new substance. He now adds hydrochloric acid to a portion of pyrolusite and after a while he notices a greenish gas arising from the vessel. This commands his full attention, as he does not recall any vapor that is like this. He sniffs the gas and finds that it has a sharp, suffocating odor. He is puzzled. What can this be? He is so handicapped by lack of knowledge! He does not know his acid is composed of hydrogen and chlorine. And he does not know the pyrolusite contains manganese dioxide. And he can never guess that the mineral is oxidizing the acid and thus setting the chlorine free. And, lastly, he does not realize that he has discovered a new element—*chlorine*! In fact, it is considered a compound for over 36 years, when it is finally proven to be an element by none other than the illustrious Sir Humphrey Davy.

Now back to the twentieth century, where we can prepare the same chlorine from the same materials used by Scheele with the added advantages of purer compounds, better equipment, and more knowledge . . . we hope.

Place two or three grams—no more —of manganese dioxide in the generator flask. Add hydrochloric acid through the thistle tube. Apply gentle heat and collect several bottles of the gas. The excess chlorine is allowed to bubble through a solution of sodium hydroxide where it is absorbed. Precaution must be taken, as chlorine is very poisonous. Prepare only small quantities at a time in well ventilated surroundings. Do *not* inhale the gas! If you do accidentally inhale a large quantity of chlorine, breathing ammonia fumes will help relieve irritation.

Chlorine can also be obtained from common salt. Mix equal quantities of salt and manganese dioxide (about 1 gram of each) and place in the generator. Pour dilute sulfuric acid through the thistle tube. In this reaction, hydrochloric acid is formed by the action of sulfuric acid on the salt and is immediately oxidized by the manganese dioxide.

Chlorine is extremely active as can be demonstrated by the following re-

actions: Powdered antimony sifted into a jar of chlorine will burst into flame forming antimony trichloride, $SbCl_3$. Powdered iron, heated moderately, glows brilliantly to form ferric chloride, $FeCl_3$. A piece of filter paper moistened with turpentine ignites spontaneously in chlorine, emitting large clouds of soot. Colored papers, cloths, flowers, etc., when moistened with water are bleached white by chlorine. Actually, substances are not bleached by chlorine but by the hypochlorous acid which is formed by chlorine and water. And to be still more technical, it is not the hypochlorous acid but the atomic oxygen released by this compound that is really responsible for bleaching. Or, in a nutshell, the bleaching action of chlorine is due to oxygen . . .!

Heated copper foil will burn in the gas resulting in a mist of cupric chloride, $CuCl_2$. Phosphorus burns feebly in chlorine to form the trichloride, PCl_3, or pentachloride, PCl_5, depending on the abundance of chlorine. (Use only a *very* small piece of phosphorus.) Melted sulfur unites to form sulfur monochloride, S_2Cl_2. Sodium unites with chlorine to form, obviously, sodium chloride.

To prepare synthetic salt, place a small, dry, freshly-cut piece of sodium in a jar of chlorine. It might be well to place the metal in a dry deflagration spoon; then lower into the jar. Allow to stand for about 30 minutes. Close examination will then reveal a white powder which is common table salt, although a rather expensive way to prepare it. If you are skeptical, dissolve the product in a large volume of water. Use a large container in the event all sodium has not reacted. Add silver nitrate and note the white precipitate indicative of the chloride ion. We do not recommend tasting as a method of proof.

Chlorine has many ûses. In peacetimes it is used in the purification of water to save lives. In war times it is used in poison gases to destroy lives. However, its latter use is being replaced by the atom bomb, which has been found to be much more effective. It is also used in the manufacture of dyes, drugs, explosives, disinfectants, germicidal preparations, in extracting gold from its ores and in reclaiming tin from "tin" cans.

Bromine

➤ THE NAME of bromine is derived from the Greek, meaning "a stench." And after you have performed this experiment you will no doubt agree that it has been appropriately named. Not only is the odor disagreeable, but also very irritating to the eyes and respiratory tract. The liquid itself is extremely caustic and if spilled on the skin will produce severe burns which are liable to become infected and are slow in healing. All in all, a rather unpleasant substance!

The chemical properties of bromine are similar to those of its older brother, chlorine, although not quite as energetic. Therefore it is possible to displace bromine easily from its compounds with chlorine. The chlorine is prepared by adding 5 cc. of dilute hy-

drochloric acid to a small quantity of manganese dioxide in a test tube. Attach a stopper and delivery tube extending below the surface of a solution of potassium bromide in another container. Now heat the test tube slightly, allowing the gas to bubble through the bromide solution. Bromine is immediately set free and imparts a deep orange color to the solution. This aqueous solution is *bromine water*. The chlorine passes into solution as potassium chloride.

Free bromine forms a yellow color with starch which you can easily demonstrate. Prepare a starch solution by adding a pinch of starch to 25 cc. water, boiling a few minutes, then thoroughly cooling. Add to a portion of bromine water.

Similar to chlorine, bromine water also bleaches. Prepare three solutions by boiling logwood, cochineal, and litmus in water. Add a little bromine water to each of the three colored solutions.

As chlorine displaces bromine, so bromine displaces iodine. Dissolve about ½ gram potassium iodide in 10 cc. of water and add bromine water. Notice the violet coloration as iodine is set free. Adding a few drops of this solution to starch solution will form the intense blue color, offering further proof of free iodine.

While bromine is fairly soluble in water, it is much more soluble in carbon disulfide, carbon tetrachloride, chloroform, ether, and similar organic solvents. Pour a few cc. of carbon tetrachloride in bromine water and shake thoroughly. After allowing to settle, note the deeper brown color in the layer of carbon tetrachloride. The same holds true for the iodine solution previously prepared. Here the carbon tetrachloride will be colored a lovely violet.

So far our attention has been focused on bromine water. Now we shall attempt to prepare the element itself. Again caution must be stressed. Many young lab enthusiasts tend to disregard warnings as they become more experienced and confident in experimenting. Confidence is an admirable trait, but it can also lead to carelessness!

Place a *small* quantity—about ¼ gram—of manganese dioxide and an equal quantity of potassium bromide in a test tube. Add a few cc. of dilute sulfuric acid. Attach a stopper and delivery tube leading to a test tube immersed in a tumbler of cold water. Upon heating the first tube, deep clouds of brown vapor will be driven off and condense to a dark red liquid in the receiving tube.

Bromine combines directly with many metals, but less vigorously than chlorine. Throw a piece of magnesium ribbon in the bromine. It will dissolve quickly, forming a white powder which is, obviously, magnesium bromide. It finds use in medicine as a sedative.

Bromine first came to light in the year 1826, introduced by Antoine Jerome Balard who obtained it by adding chlorine to brines and distilling. It is interesting to note here that the great chemist Liebig almost discovered bromine. Earlier he had acquired an unknown substance, and

upon testing not too thoroughly, he concluded that it was a compound of iodine. When the properties of bromine were made known by Balard, Liebig realized they were identical with his substance. His "compound of iodine" was actually bromine!

Iodine

➤ IODINE, the most beautiful and most gentle member of the halogen family, first saw the light of day in 1811 when it was isolated by Bernard Courtois from the mother liquor obtained from algae. Upon adding an excess of sulfuric acid to a concentrated portion of the liquor which he prepared by extracting the ashes of marine plants with water, Courtois was no doubt greatly surprised to see lovely clouds of deep violet vapor arising from the liquid. He found that this vapor would condense to form dark lustrous crystals, and that these crystals would combine directly with certain metals, with phosphorus and with hydrogen. Later investigation by Gay-Lussac proved the substance to be a new element and it was christened *iodine,* from the Greek word meaning "like a violet."

To prepare iodine, mix together 2 grams potassium iodide and 3 grams manganese dioxide. Transfer the mixture to a small beaker and add 10 cc. of dilute sulfuric acid. Gentle heat will produce clouds of violet iodine vapor. Place a flask of cold water over the beaker, or cover the beaker partially with an evaporating dish. Crystals of iodine will form on the bottom of the flask or dish. The iodine passes from the gaseous state directly to the solid state. This process is known as *sublimation.* Scrape crystals off and dry them on blotting or filter paper.

To the average person iodine is known only in the form of the tincture, used as an antiseptic, which is a solution of iodine in alcohol. The medicine-cabinet variety usually contains 2% iodine. Although some people prefer the bright red of Mercurochrome to the brown of iodine, the latter's efficiency as an antiseptic cannot be denied.

Iodine will also dissolve in carbon tetrachloride or disulfide, forming a violet solution.

Another antiseptic compound of iodine is *iodoform,* CHI_3, a yellow powder with a characteristic "antiseptic" odor. Dissolve iodine crystals in potassium iodide solution until the liquid is dark brown in color. Add 5 cc. of this solution to an equal amount of alcohol. Now add sodium hydroxide solution in small proportions until the brown color disappears. Upon heating a few minutes and then cooling, a yellow precipitate of iodoform will separate out.

Another and perhaps better method of preparing iodoform is by dissolving 1 gram of potassium iodide in 20 cc. of water and adding 1 cc. of acetone. To this mixture add a dilute solution of sodium hypochlorite (you can use "Chlorox" from the grocery store). The yellow precipitate of iodoform is immediately formed.

The direct combination of iodine and phosphorous forms an exciting

demonstration as these two elements celebrate their union with a spontaneous display of fire. In a large evaporating dish, carefully place a *very small* piece of white phosphorous. Drop on the phosphorous a few small crystals of iodine. Keep your face a safe distance away. The mixture will suddenly burst into a brilliant flame, evolving large clouds of smoke. The result of this elaborate performance is a red compound, phosphorous triiodide, PI_3.

With red phosphorous, the action is much milder. If water be added to the mixture of red phosphorous and iodine, hydrogen iodide is formed:

$$2P + 3I_2 \rightarrow 2PI_3.$$
$$PI_3 + 3H_2O \rightarrow 3HI + H_3PO_3.$$

Speaking of hydrogen iodide, one would suppose it could be formed by the addition of sulfuric acid to an iodide (similar to hydrogen chloride). But such is not the case. Add a little sulfuric acid to a few crystals of potassium iodide in a dry test tube. You will notice the violet vapor of iodine and if you smell at the mouth of the tube you will no doubt recognize the delightful aroma of hydrogen sulfide. Now how did hydrogen sulfide get into the picture? Well, it appears that iodide was temporarily formed, but being much less stable than hydrogen chloride, it is therefore a more active reducing agent. And the nearest thing around for it to reduce is the sulfuric acid, which it promptly reduces to hydrogen sulfide:

$$H_2SO_4 + 8HI \rightarrow H_2S + 4H_2O + 4I_2$$

If you add a solution of sodium thiosulfate to a solution of iodine in potassium iodide, the brown color will entirely disappear. Hence this thiosulfate is an effective agent for removing iodine stains. You may use it to remove any brown stains you have acquired on your hands. Of course, if you have been a careful worker, there will be no stains to remove!

Fluorine

➤ THE ISOLATION of fluorine, the most active of all elements, required many long years of dangerous and painstaking research. Davy, Gay-Lussac, Thenard, the Knox brothers, Fremy and Gore were among the many noted chemists who tried unsuccessfu'ly to free fluorine from its compounds. Louyet and Nickles both succumbed to the poisonous vapors of hydrogen fluoride and thus died martyrs to science in their efforts to obtain the elusive fluorine. The long search finally ended when Moissan liberated the element in 1886, after many unsuccessful attempts and much suffering from inhaling hydrofluoric acid vapors. His method consisted of the electrolysis of dry potassium bifluoride dissolved in anhydrous hydrofluoric acid cooled to a temperature of $-23°$. He used platinum-iridium electrodes in a platinum U-tube covered with fluospar caps.

Assuming that the average home lab is not equipped with the elaborate apparatus necessary for the preparation of fluorine, we must confine our interests to the properties of the compounds of fluorine. All fluorides are poisonous and therefore must be handled carefully. Hydrofluoric acid is

extremely caustic causing painful sores if spilled on the skin; its vapor is irritating and must not be inhaled.

Etching Glass

Although hydrofluoric acid is a relatively weak acid and reacts slowly upon metals, it is unique in that it reacts readily with silica and silicates: $CaSiO_3 + 6HF \rightarrow SiF_4 + CaF_2 + 3H_2O$. Hence it attacks glass, porcelain, claywares, etc. This property is utilized in the etching and frosting of glass articles.

Cover the article to be etched with a thin coating of wax. The design or lettering is then made by cutting through the wax with a sharp instrument. The hydrofluoric acid vapors will attack that portion of the glass exposed producing a rough surface. Burettes and other glass ware are graduated in this manner.

To prepare the hydrofluoric acid, mix 1 gram of calcium fluoride with enough sulfuric acid to form a thin paste. The mixture must be placed in a lead dish. Or if you have a few platinum or iridium dishes, they may be used instead. Now place the wax-coated glass over the dish and allow to stand overnight. The action can be hastened by gently warming the dish, but care must be taken not to melt the wax and thus spoil the design. After sufficient exposure to the acid vapors, the wax is removed by melting, leaving the etched outline of the design on the glass.

Fluosilicates

When con. sulfuric acid is added to a small quantity of a mixture of silica and calcium fluoride, silicon tetrafluoride, a gas, is given off. This gas dissolves readily in water, forming silicic acid and fluosilicic acid. The former can be removed by precipitation, leaving the latter in solution:

$$3SiF_4 + 4H_2O \rightarrow H_4SiO_4 \downarrow + 2H_2SiF_6$$

Potassium fluosilicate (or silicofluoride) is one of the few salts of this metal which is insoluble in water. For this reason, fluosilicic acid is used in analysis. If potassium chloride solution be added to the fluosilicic acid, a translucent and gelatinous precipitate is formed which will be increased by the addition of alcohol.

Organic Fluoro Compounds

Recently many new fluoro compounds have been prepared with the possibilities of many more yet to be investigated.

One of the most useful of these compounds is dichlorodifluoromethane (CCl_2F_2), commonly known as "freon" which is widely used as a refrigerant. It is ideal for this purpose and is rapidly replacing sulfur dioxide, ammonia, and methyl chloride in both household and commercial refrigeration. It is stable, non-poisonous, non-flammable, non-corrosive and has very little odor. It is formed by the action of antimony trifluoride on carbon tetrachloride, using antimony pentachloride as a catalyst. The net result of this reaction is the replacement of two chlorine atoms in carbon tetrachloride by fluorine:

$$3CCl_4 + 2SbF_3 \rightarrow 3CCl_2F_2 + 2SbCl_3$$

The Newest Halogen

There has been a new arrival at the Halogen Family! In fact it is so new, very litle is known about it.

It has been made synthetically by bombarding bismuth with alpha particles and has been christened *Astatine*. Much research must be done before definite properties of the new halogen are established.

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